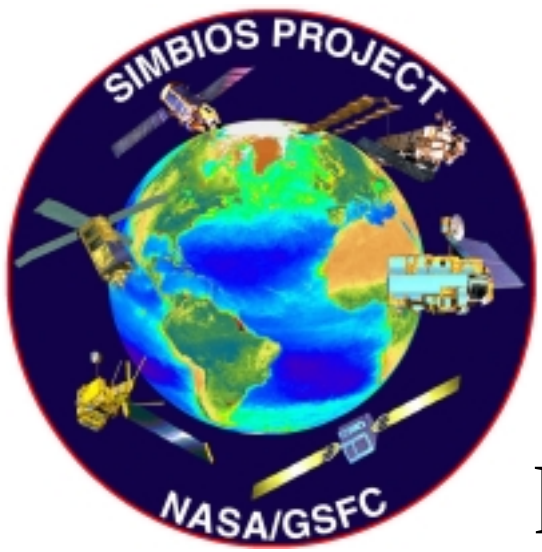
Why oceanography from space ?



Giulietta Sara Fargion

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GSFC Mail Code 970.2
Greenbelt, Maryland, USA

http://simbios.gsfc.nasa.gov

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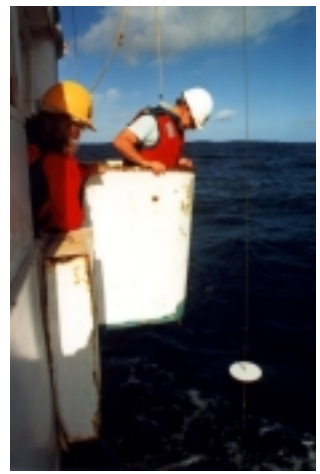
the classic oceanography ….



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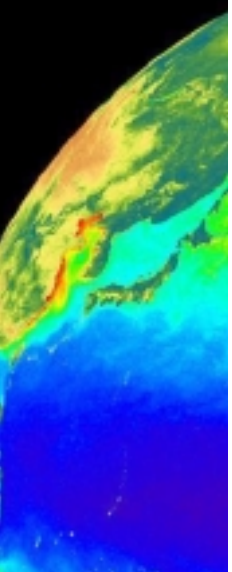

- California Cooperative Oceanic Fisheries Investigations program was established in 1949 to guide research efforts focused on the causes of the massive failure of the Pacific sardine fishery off California and Mexico.
- The central theme since its founding in 1949 has been to conduct cooperative biological-oceanographic surveys that measure the physical, chemical, and biological characteristics of the California Current region.
- In May 1997, the CalCOFI data base was identified as a national science treasure

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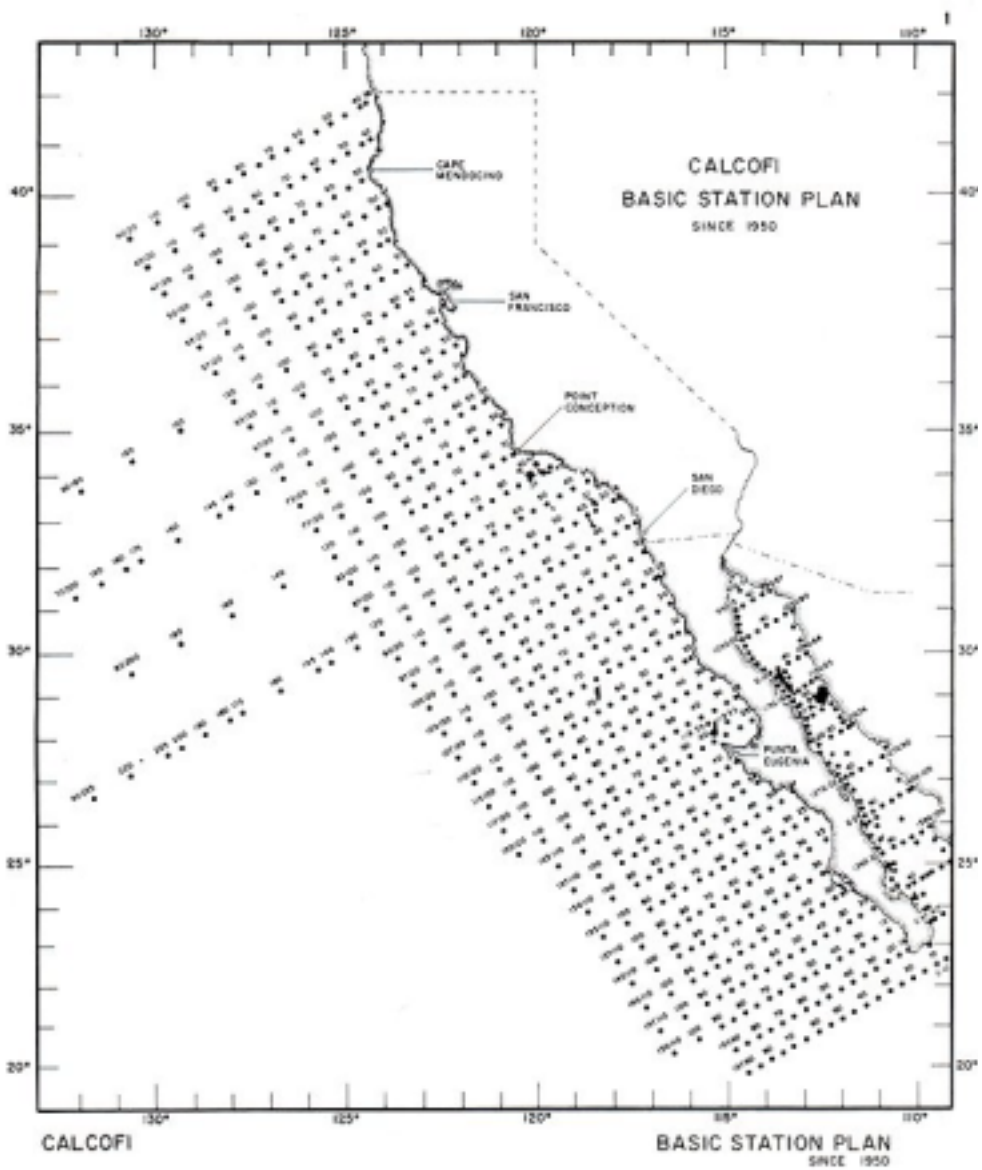
CalCOFI time series: 1949-on



CalCOFI has gained an international reputation as a model for the study of pelagic populations and the large-scale meteorological and oceanographic events which affect them.

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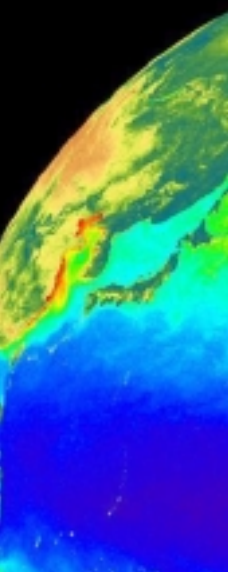

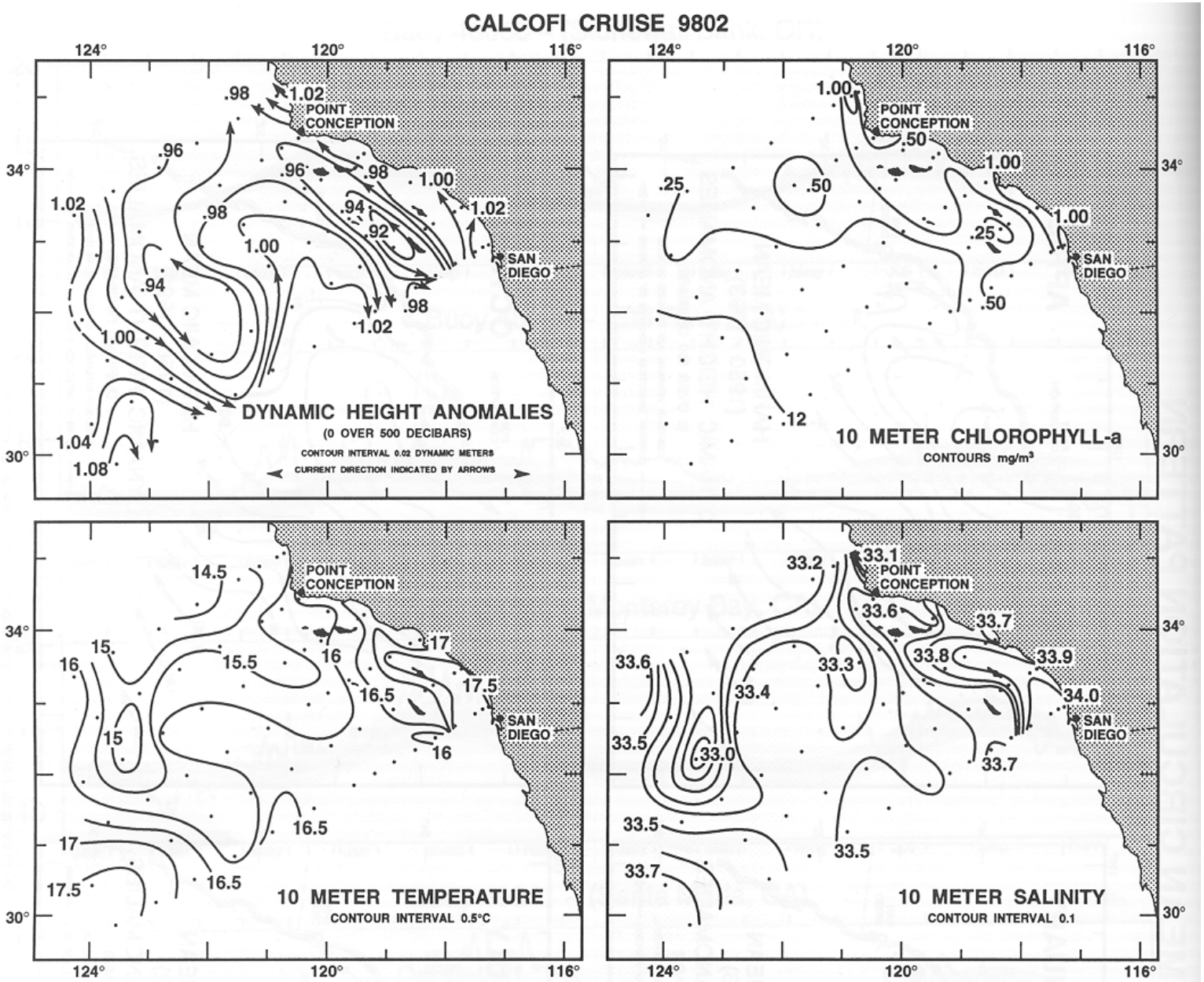

Figure 11. Spatial patterns for CalCOFI cruise 9802 (23 January–14 February 1998), including upper-ocean geostrophic flow estimated from 0 over 500 db dynamic height anomalies, 10 m chlorophyll, 10 m temperature, and 10 m salinity.

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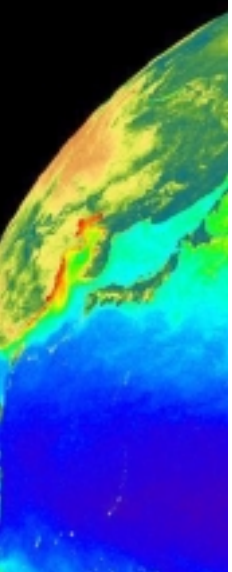
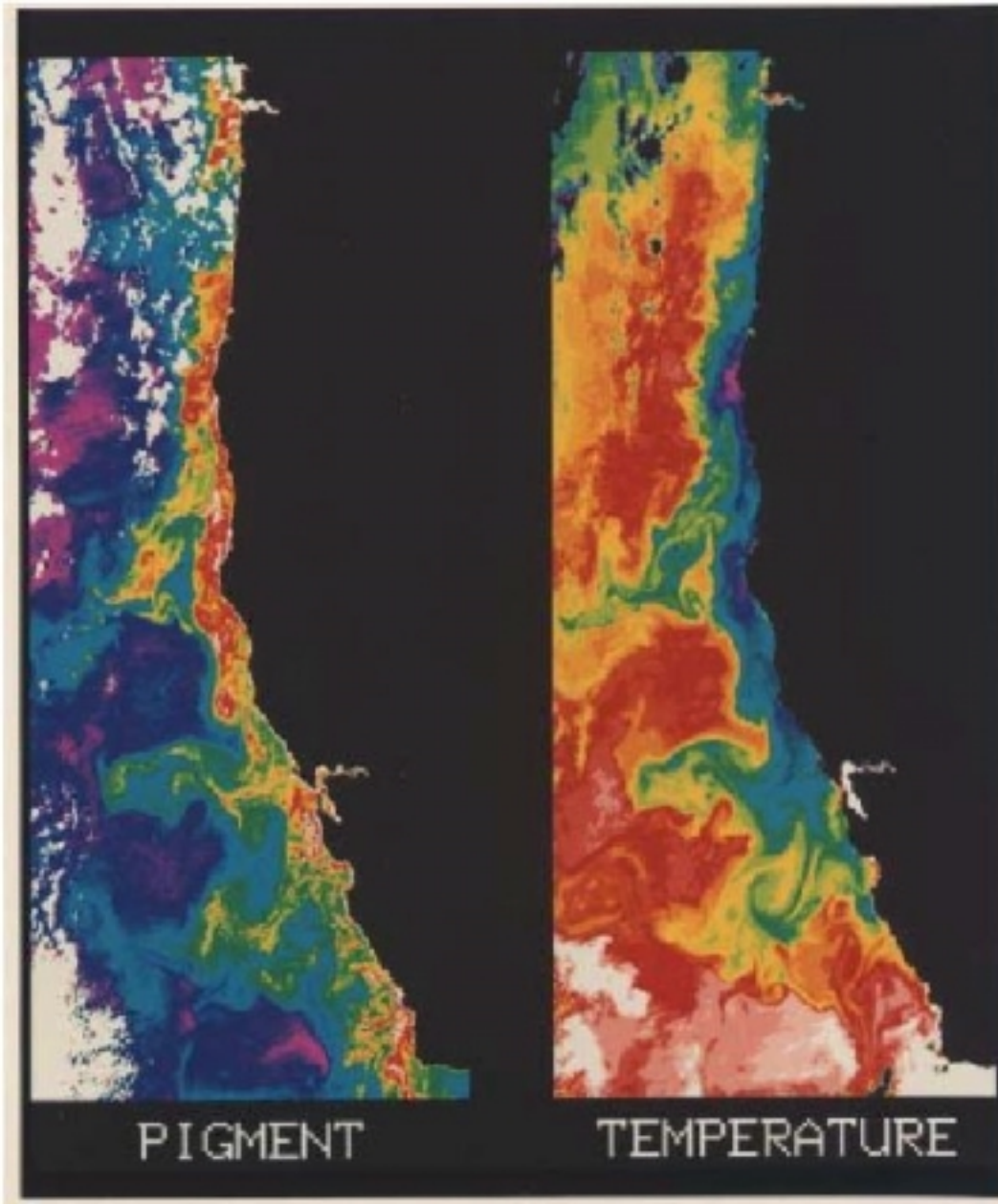


Despite 40 years' of sampling, CalCOFI missed one of the dominant features of the California Current!



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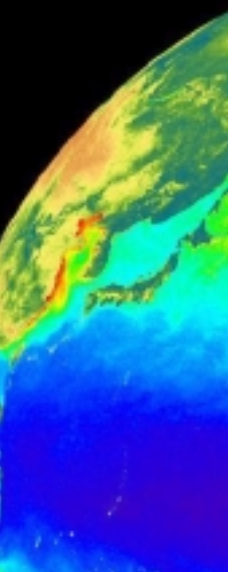

Satellite Oceanography:

Why use a sampling platform hundreds of Kilometers away from the object of study?

Space and time scales

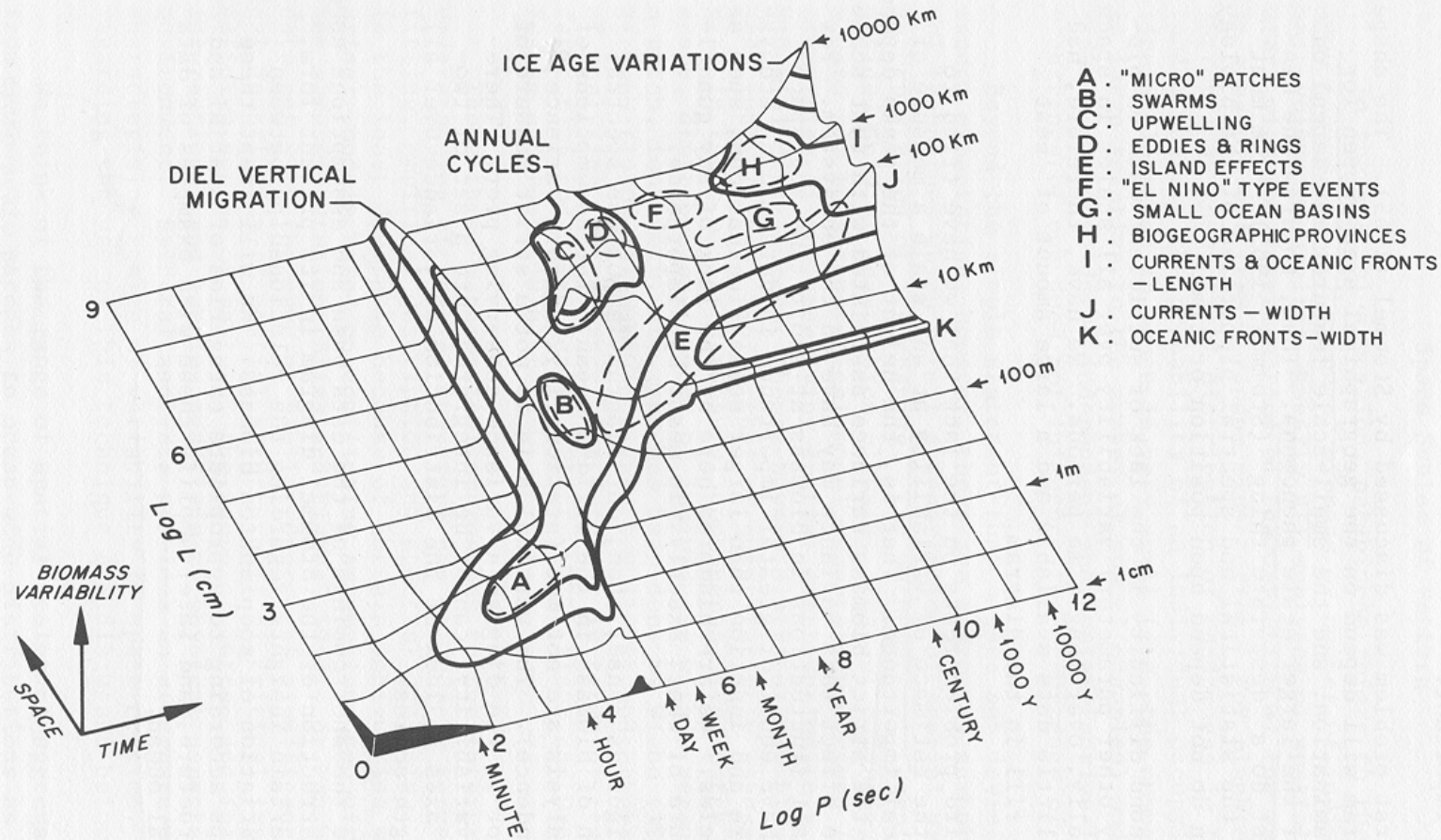

Figure 1. The Stommel Diagram, a conceptual model of the time-space scales of zooplankton biomass variability and the factors contributing to these scales. I, J and K are bands centered about 1000's, 100's and several kilometers in space scales, with time variations between weeks and geological time scales.

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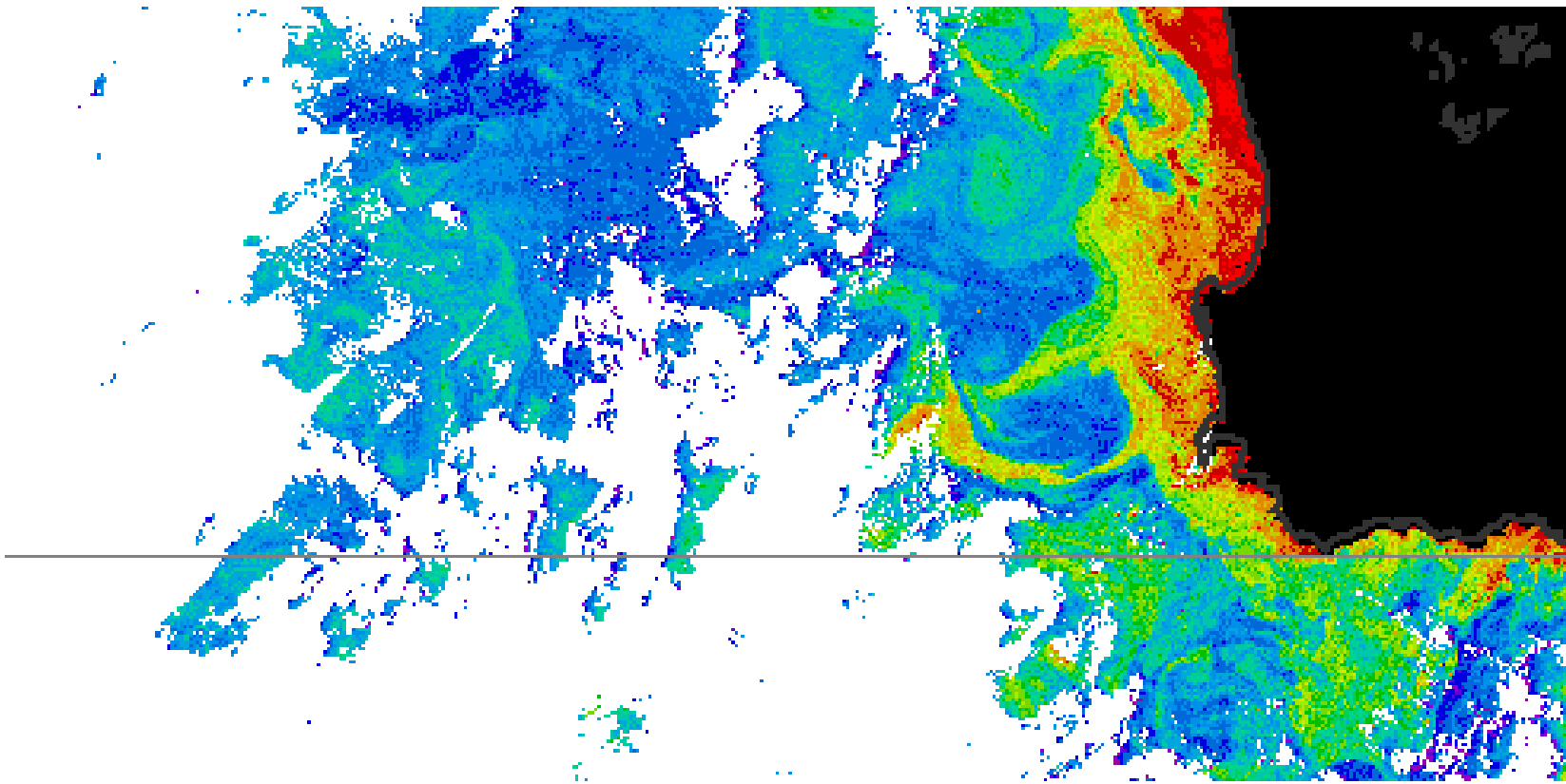
The Benguela upwelling zone: jets, eddies, filaments

Space scale: 1-100Km

Time scale: 1day - months



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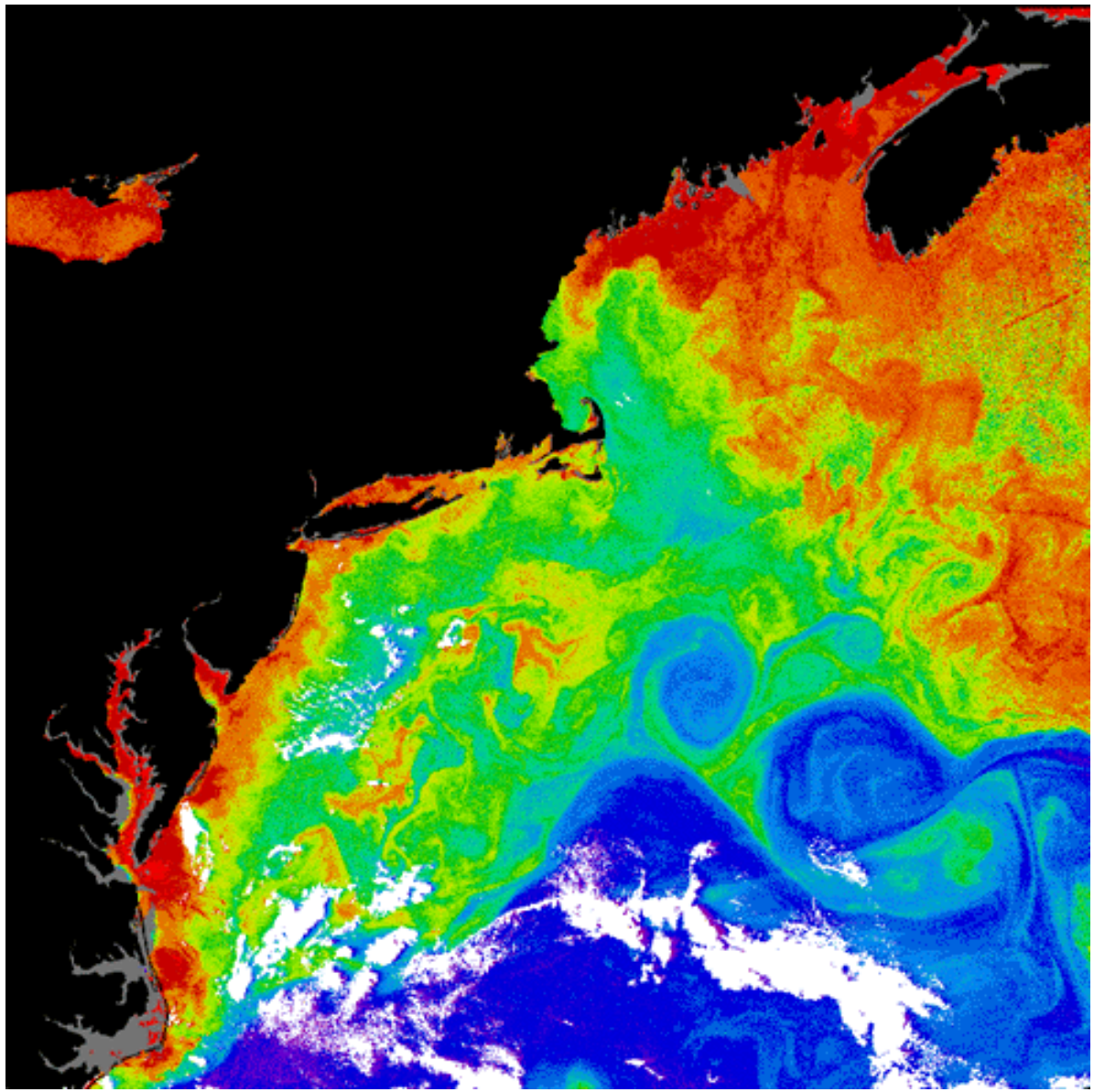
Time scale: 1 day - century



FRONTS:

The Gulf Stream marks the dividing line between warm, low-productivity waters to the south and colder, more productive waters near the North American continental shelf.

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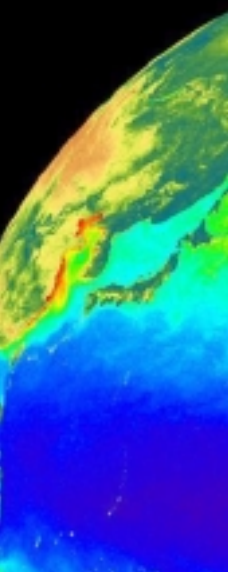

Why use a sampling platform hundreds of Kilometers away from the object of study?

- synopticity: having an overall view of a large part of the ocean in a short period of time
- the capacity of satellites to sample densely and rapidly over large areas (improving our knowledge of horizontal spatial structures)
- repetitive coverage (identified changes through time and provide insight into the mechanisms generating and modifying spatial patterns)

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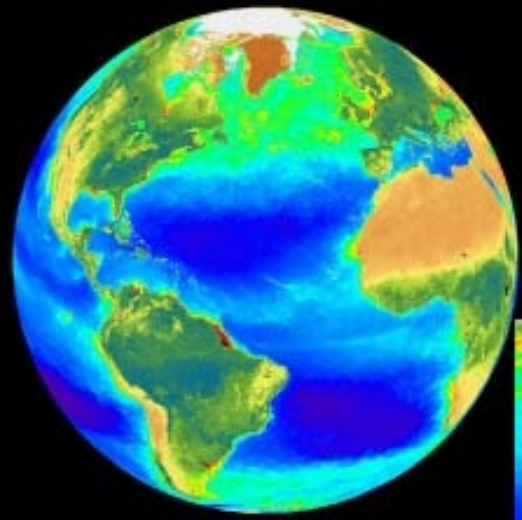
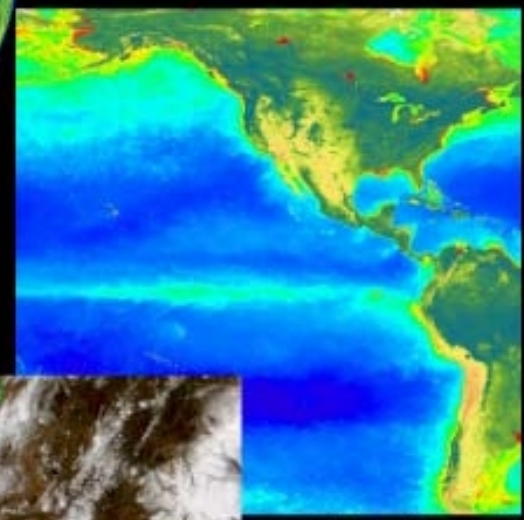
SeaWiFS:

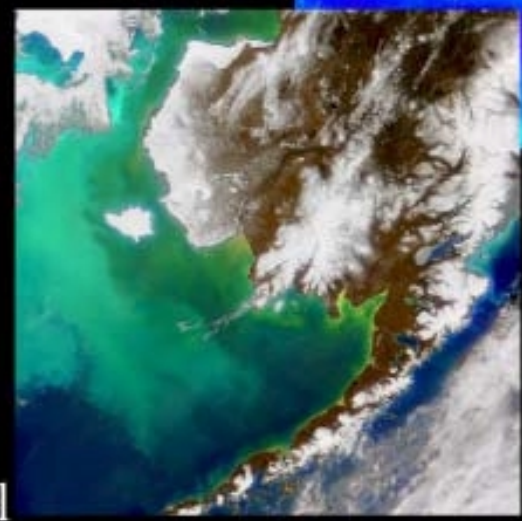
Spanning Key Time and Space Scales



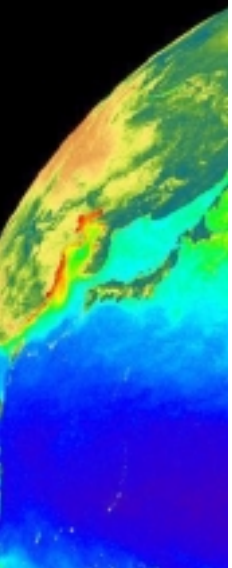
Global



Regional



Local



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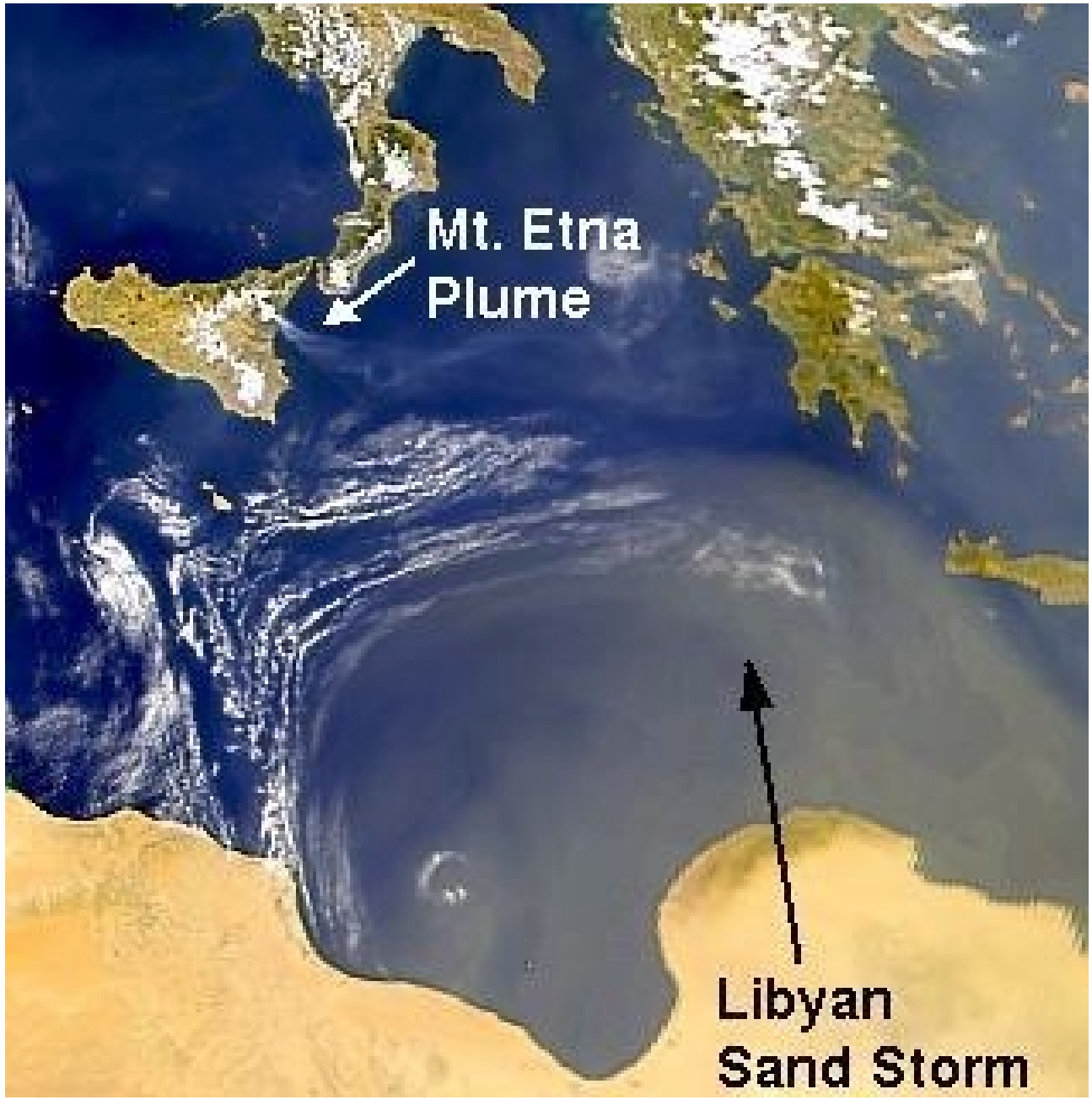
Events like the eruption of Mount Etna and Libyan Sand Storm on Friday, July 27, 2001



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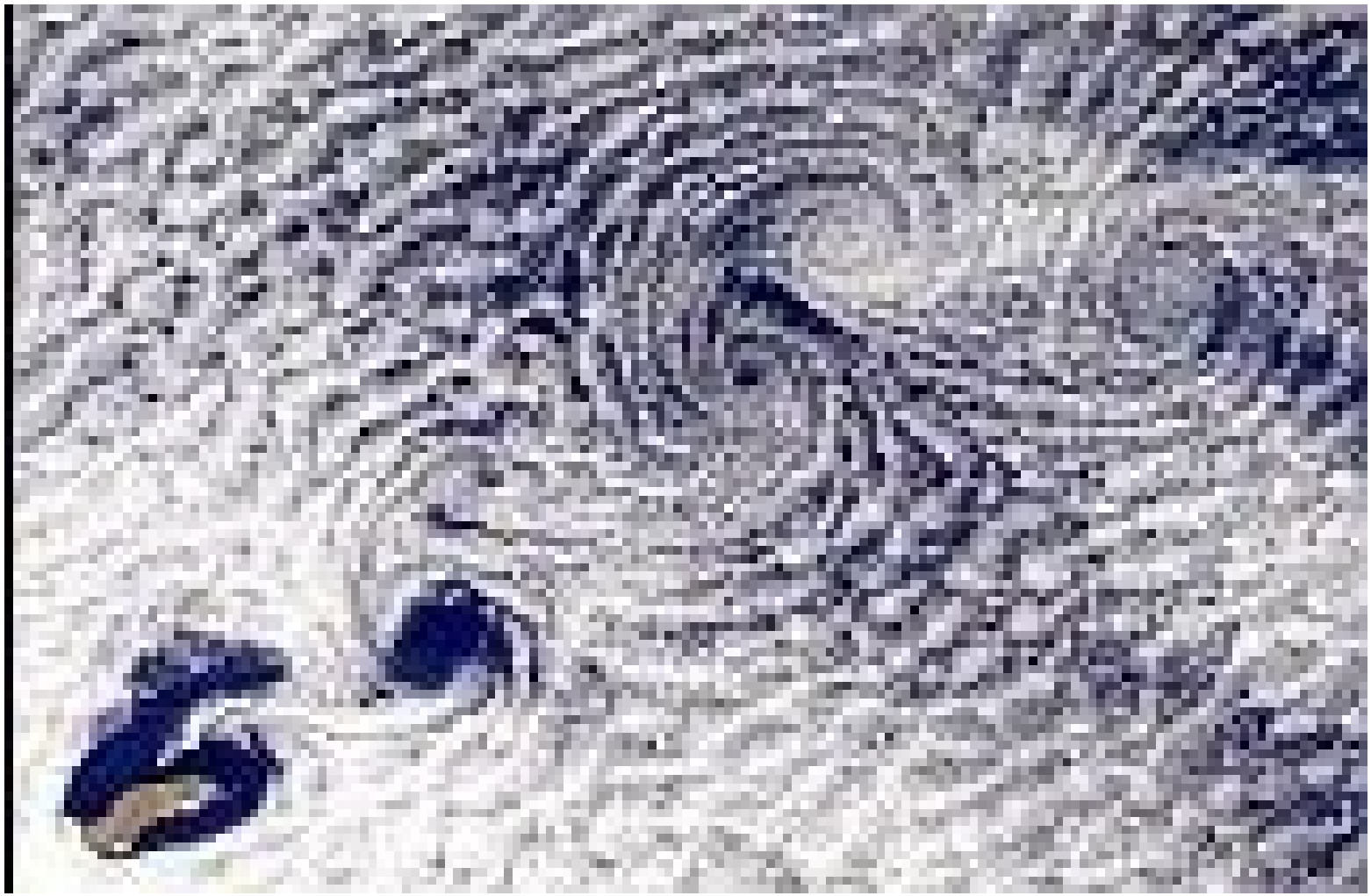
Observed satellite oceanographic features have generated field studies



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Why this color ?

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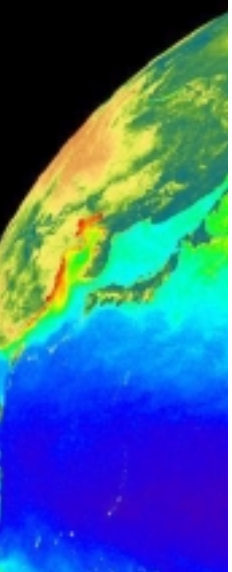
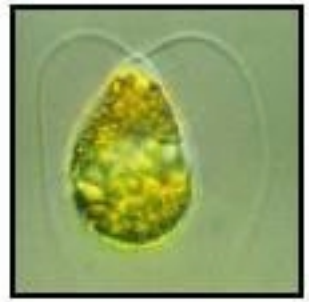


For most of the world's oceans, the most important things that influence its color are PHYTOPLANKTON.

- Phytoplankton are very small,single-celled plants, generally smaller than the size of a pinhead that contain a green pigment called chlorophyll. All plants (on land and in the ocean) use chlorophyll to capture energy from the sun and through the process known as photosynthesis convert water and carbon dioxide into new plant material and oxygen. Although microscopic, phytoplankton can bloom in such large numbers that they can change the color of the ocean to such a degree that we can measure that change from space.

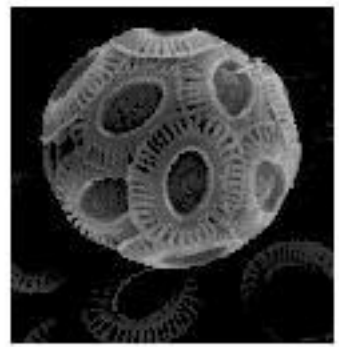
- The basic principle behind the remote sensing of ocean color from space is this: the more phytoplankton in the water, the greener it is....the less phytoplankton, the bluer it is.

Chlorophytes



Euglenophytes

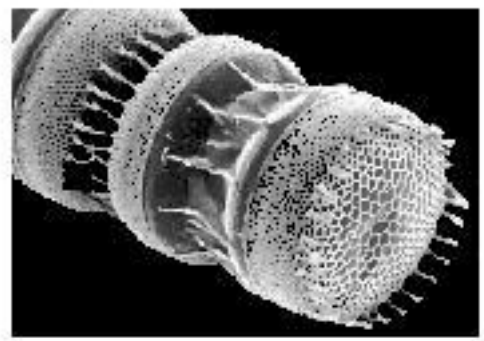
Haptophytes

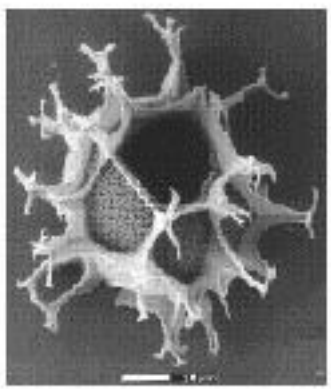


Diversity

Glaucophytes

Bacillariophytes





Pyrrophytes (dinoflagellates)

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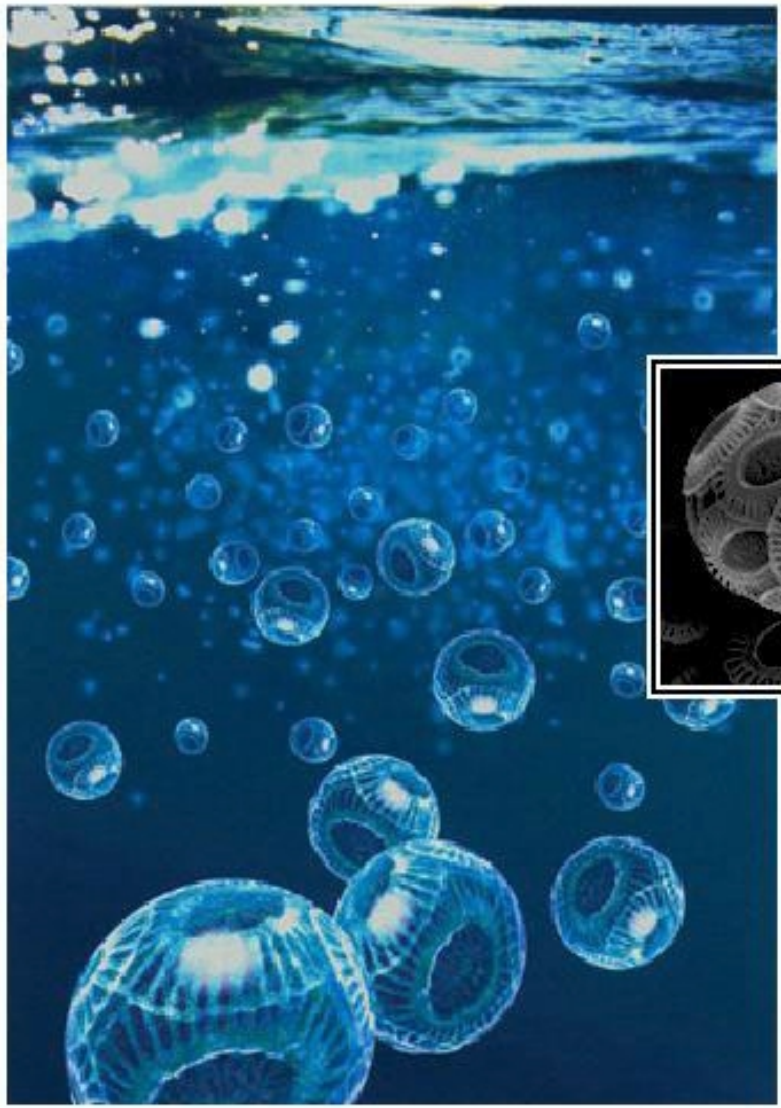
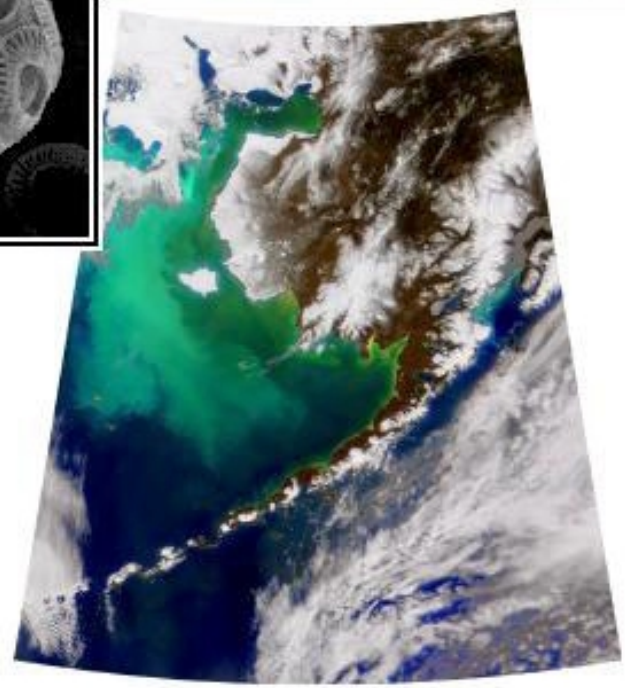
Coccolithophorid Blooms





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Dinoflagellates: red tides

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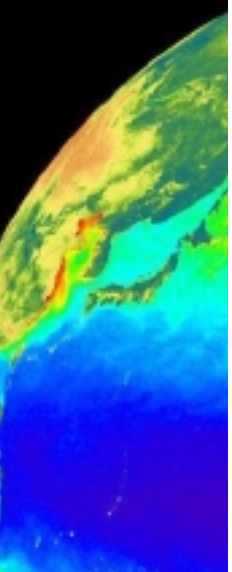

Something about the pathways of light reaching the remote sensor

- We want to measure the “color” of the ocean, but we actually measure ocean + atmosphere.
- The atmosphere is 90% of the signal and it must be accurately modeled and removed

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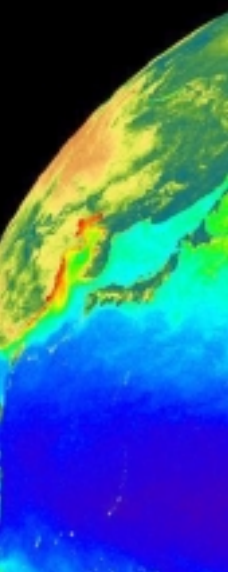


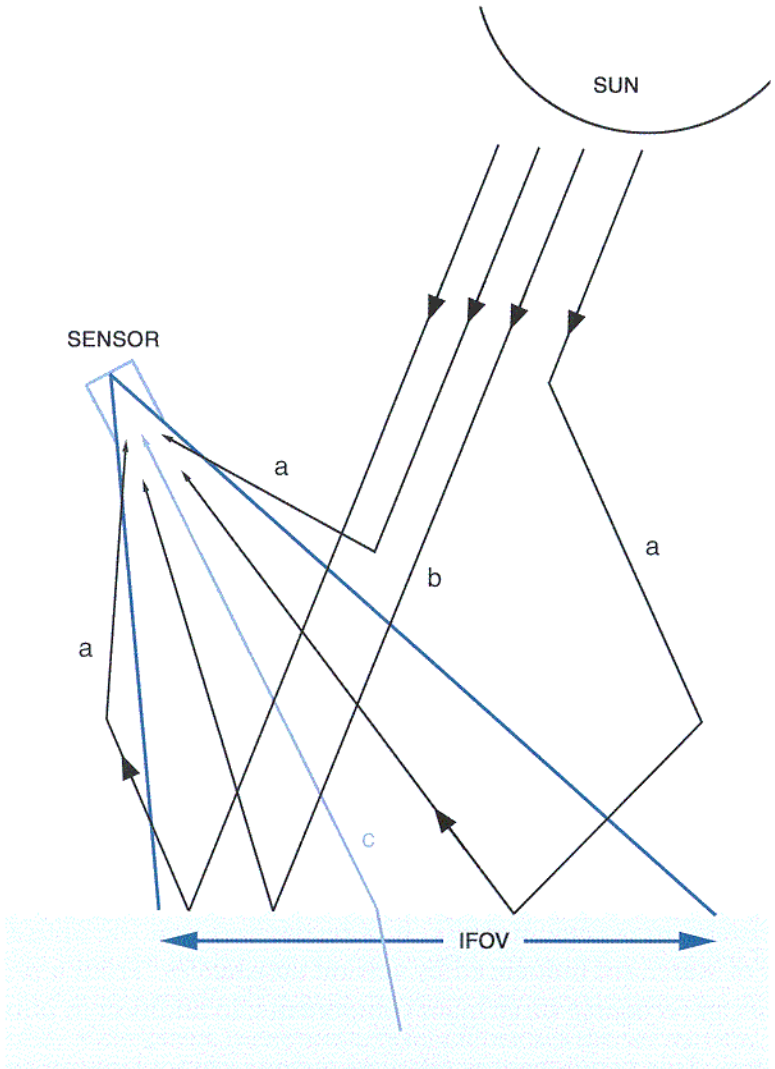
Pathways of light reaching the remote sensor:

(a) light scattered by atmosphere - multiple scattering is possible;
(b) specular reflection of direct sunlight at sea surface
(c)upwelling light leaving the water surface and travelling in the direction of the sensor

Instantaneous field of view (IFOV)

The geometry of the sensor, its altitude and its viewing angle determine IFOV or **pixel size** of the sensor

We need to have an atmospheric correction



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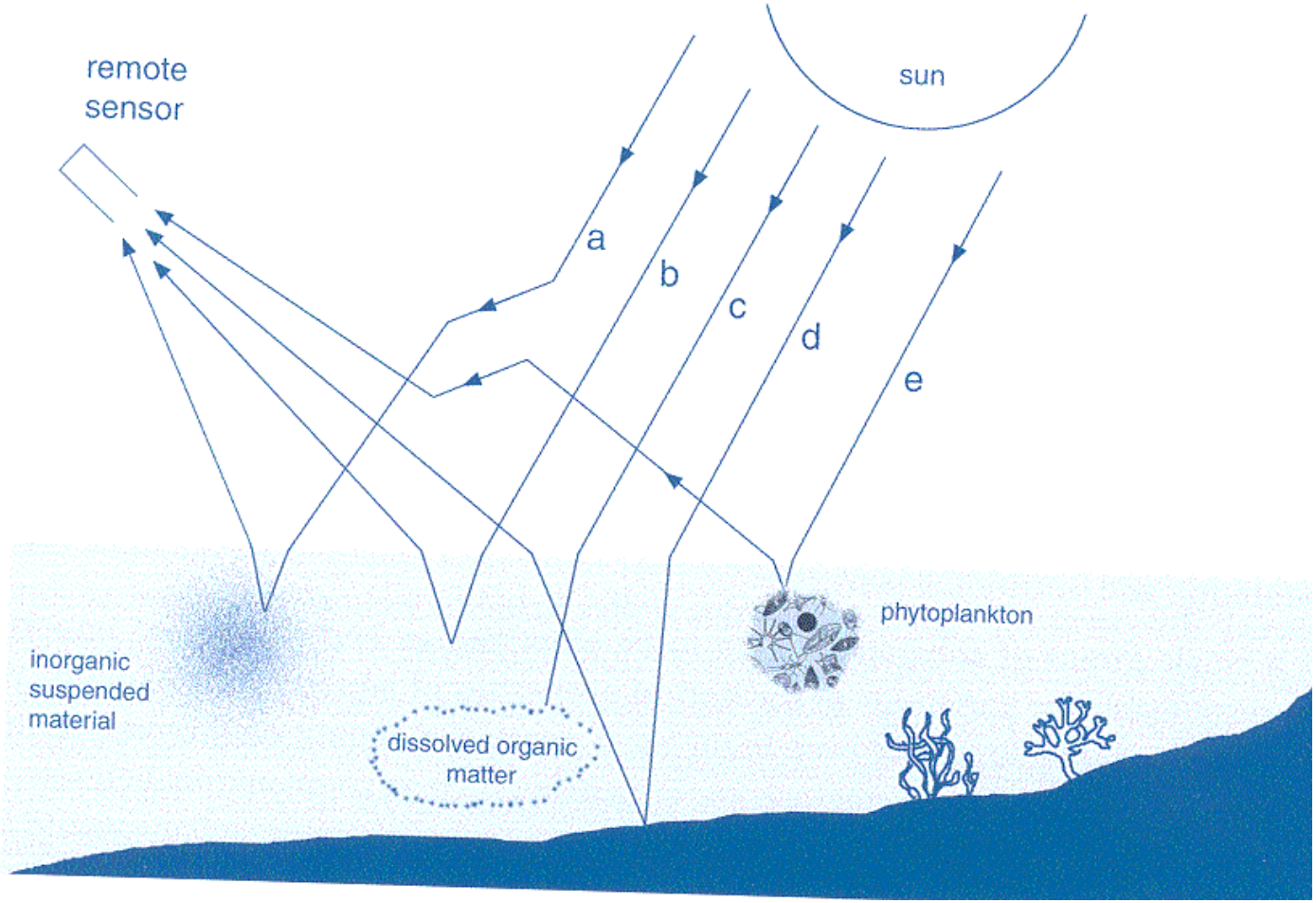
We need to have a bio-optical algorithm



Factors that influence upwelling light leaving the sea surface

(a) upward scattering by inorganic suspended material;
(b) upward scattering from water molecules;
(c) absorption by yellow-substances component (detrital component);
(d) reflection off the bottom; and
(e) upward scattering from phytoplankton component

Some limitations to consider

- The oceanographic knowledge obtained is limited to information that can be encoded in and conveyed by electromagnetic radiation.
- water is a poor transmitter of this radiation, only upper-layer or ocean surface properties can be directly estimated
- the atmosphere interferes with the electromagnetic radiation that carries the oceanographic information, introducing noise and degrading the signal
- for the visible and infrared data, cloud cover can be a problem in some regions of the world's oceans

$\longmapsto$ limits to the accuracy

Satellite should be coupled with in situ measurements

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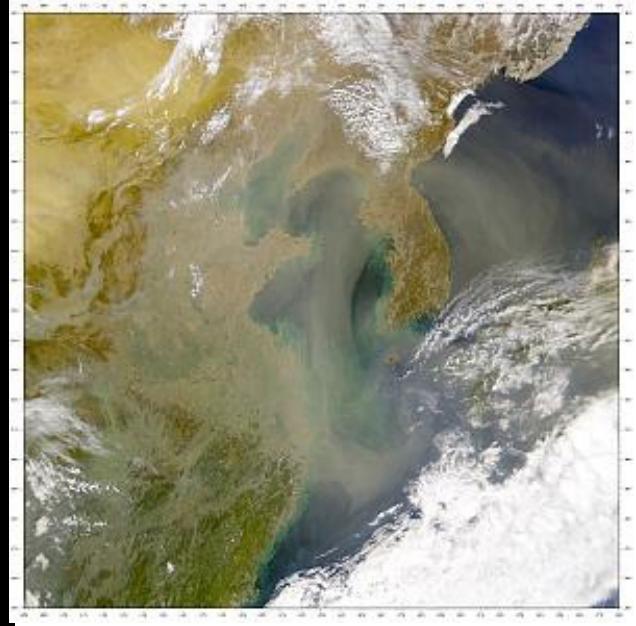
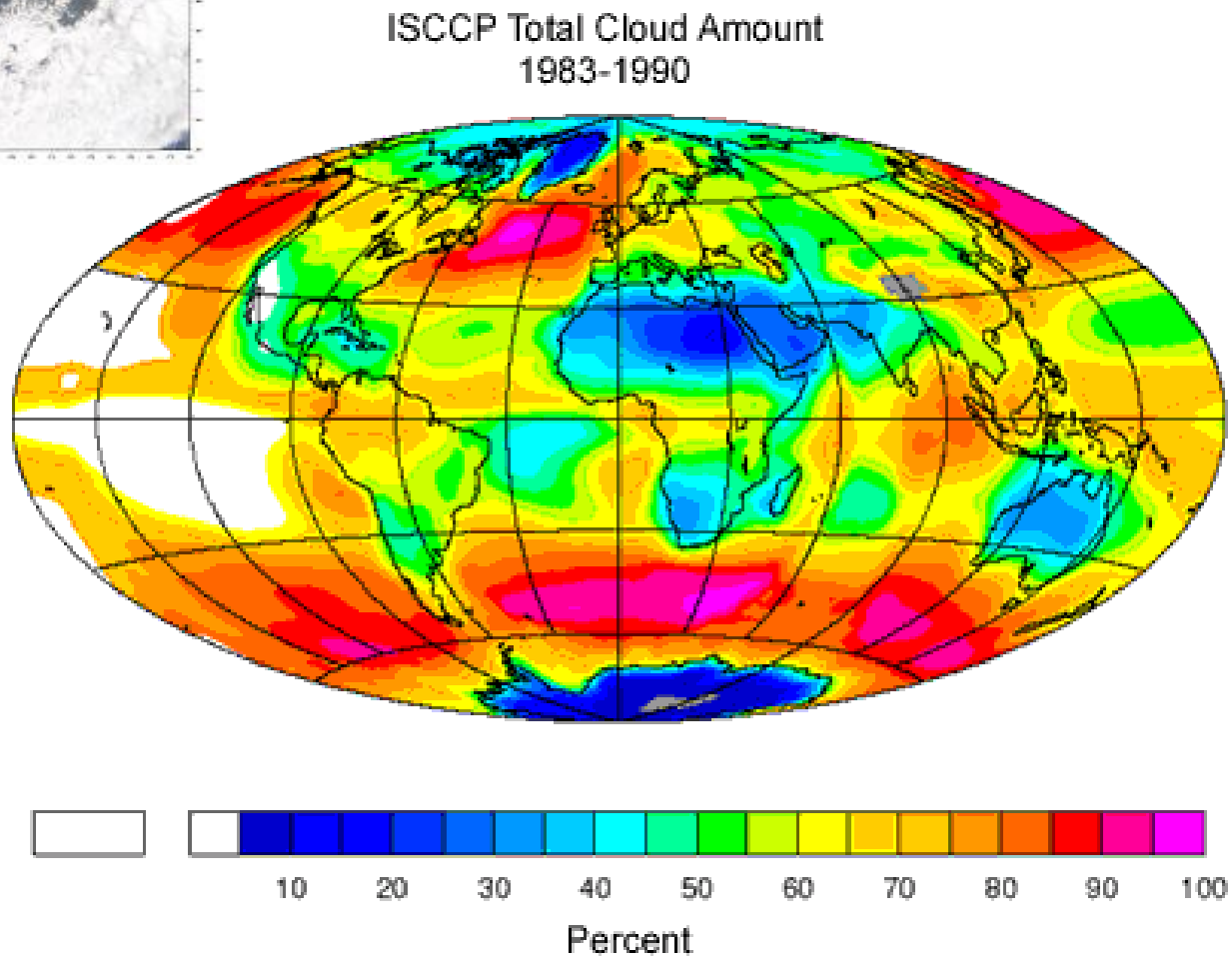


a world of clouds….



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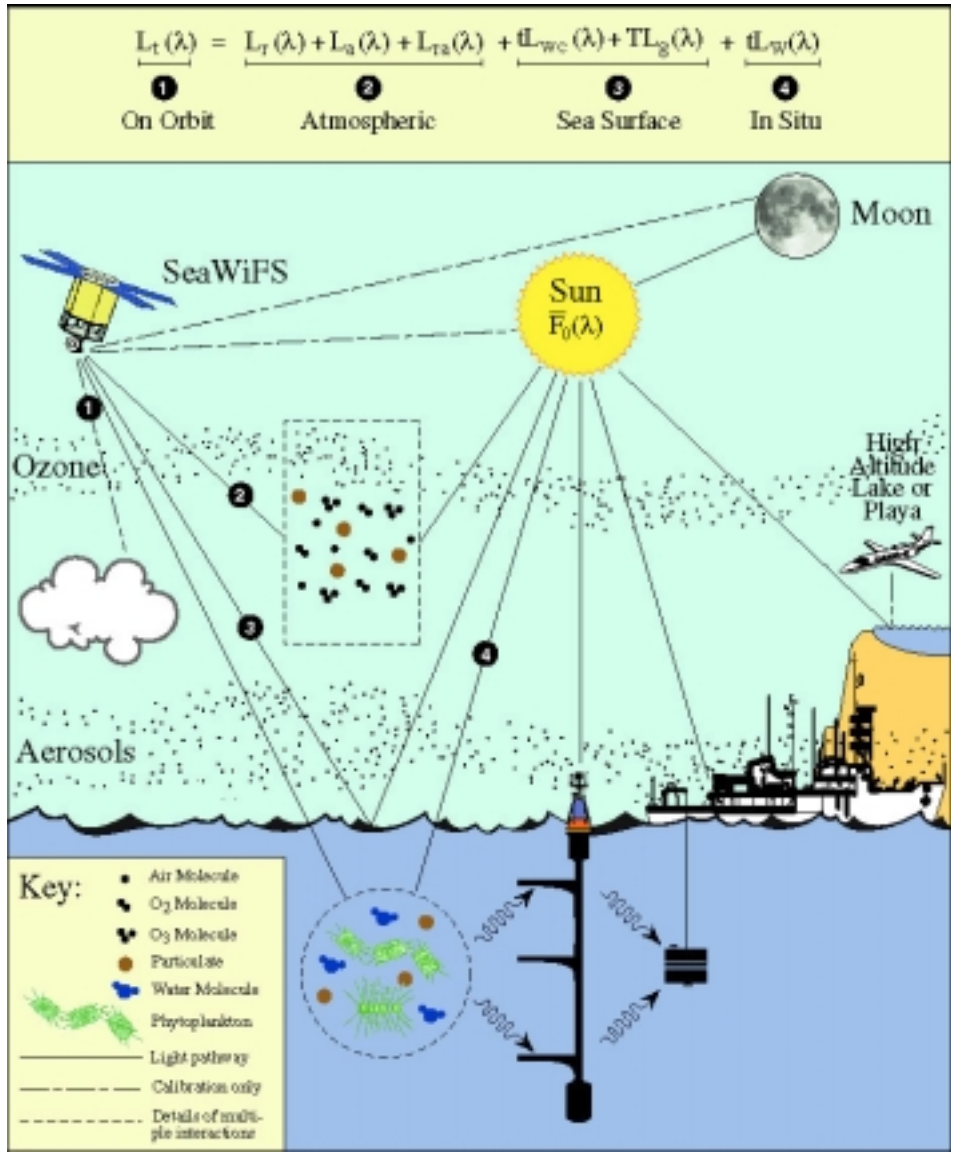
Calibration Paradigm

SeaWiFS Project uses a variety of calibration approaches:

- **Laboratory** - before launch, sensor is calibrated in lab
- **On-orbit** - daily solar and monthly lunar observations are used to track changes in sensor response
- **Vicarious** - comparison of data retrievals to in-water, ship, and airborne sensors is used to adjust instrument gains



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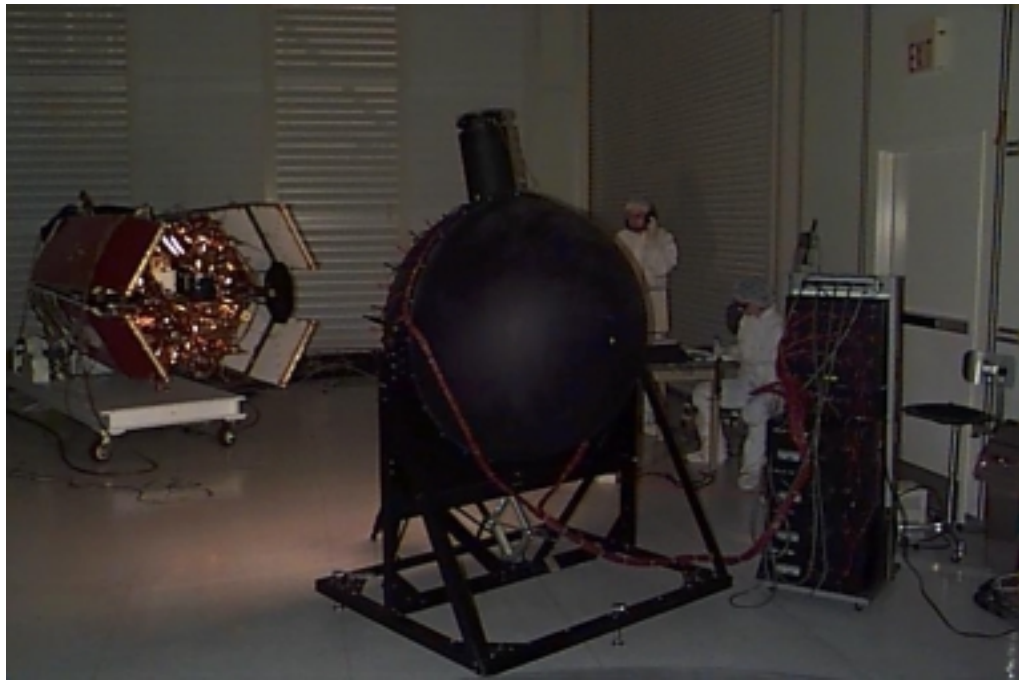

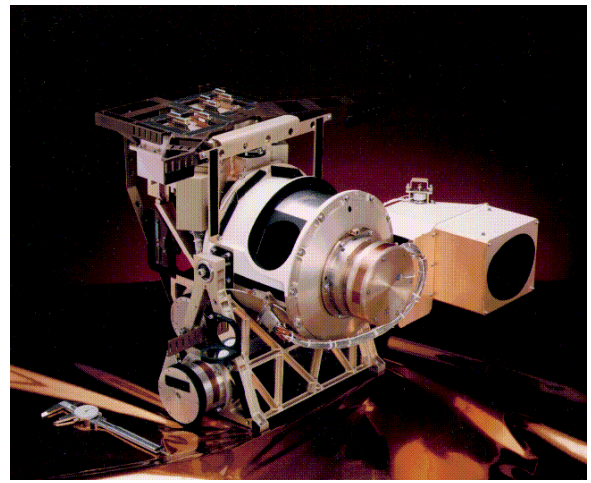

SeaWiFS prelaunch radiometric calibration and spectral characterization

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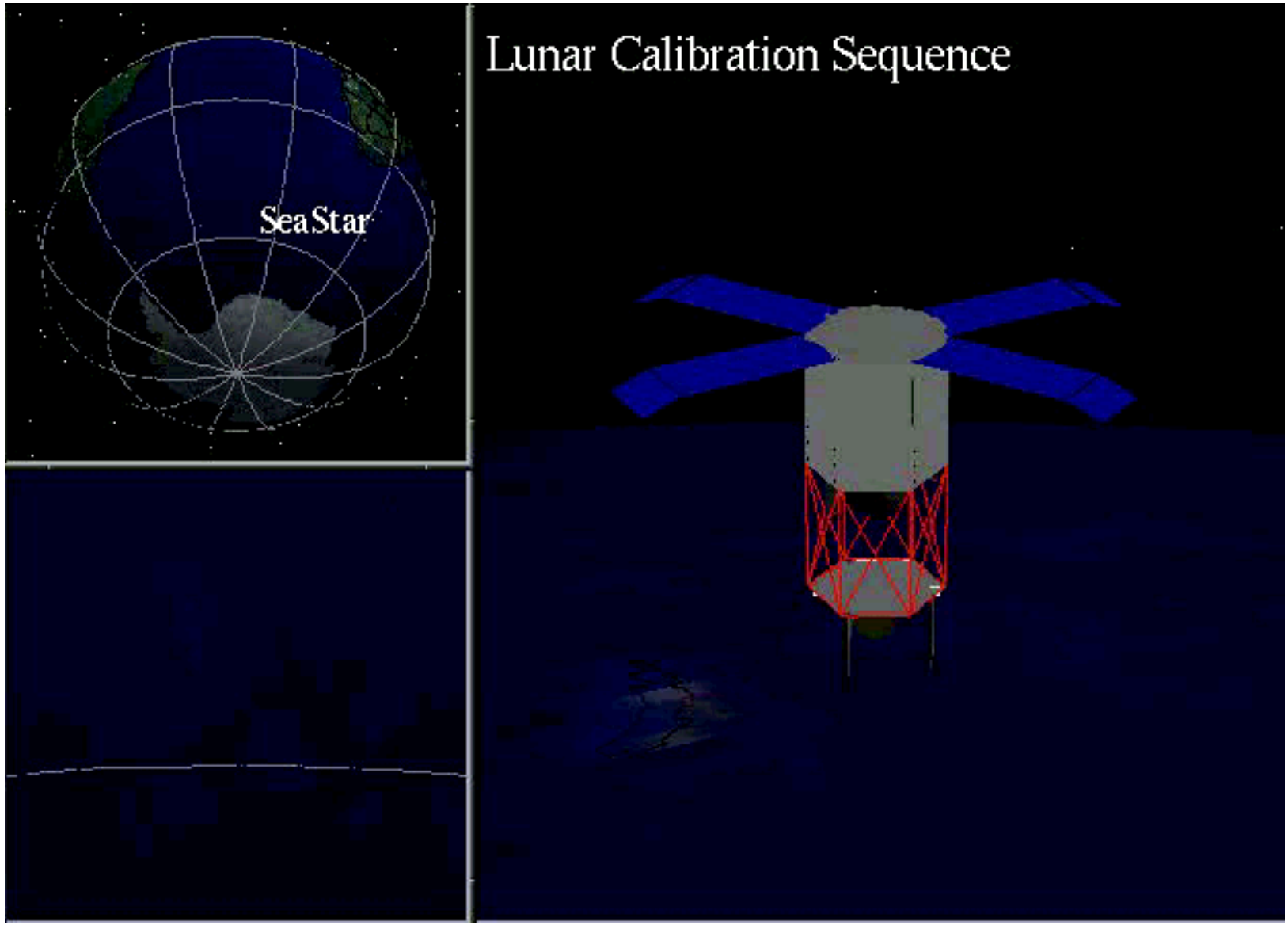
Lunar calibration Sequence



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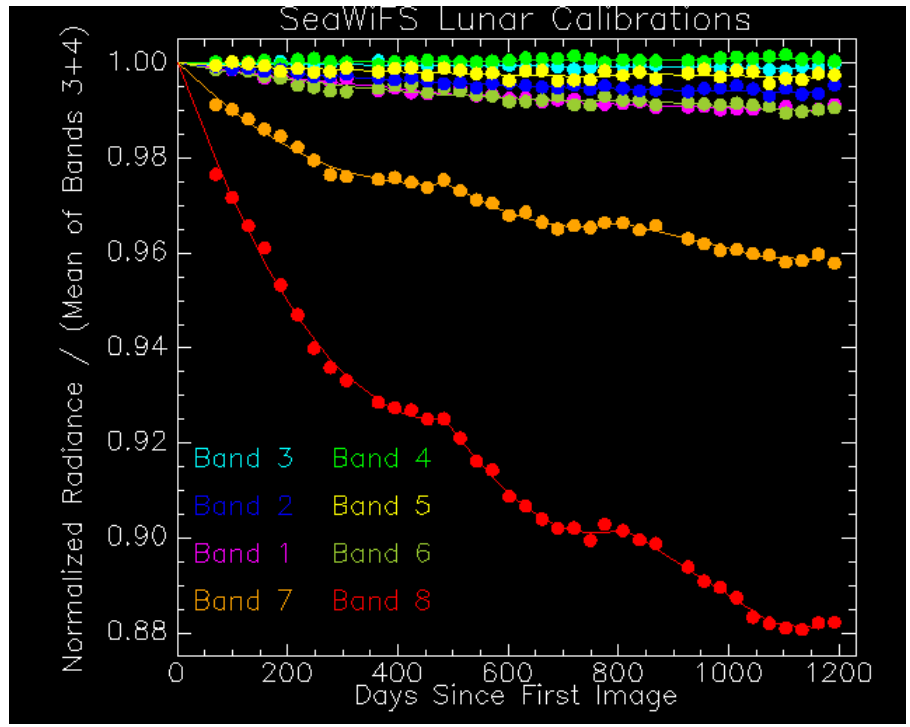
Lunar Calibration

Once a month the SeaWiFS satellite is rotated to observe the Moon

- 3 years of observations show reasonable sensor stability
  - long term calibration stability is better than 1.0%
  - absolute calibration uncertainty is 4%
  - short term calibration stability is better than 1 count



- variations are incorporated into processing algorithms
- time-dependent gain and offset terms are updated as required
- calibration tables are distributed through the Goddard DAAC

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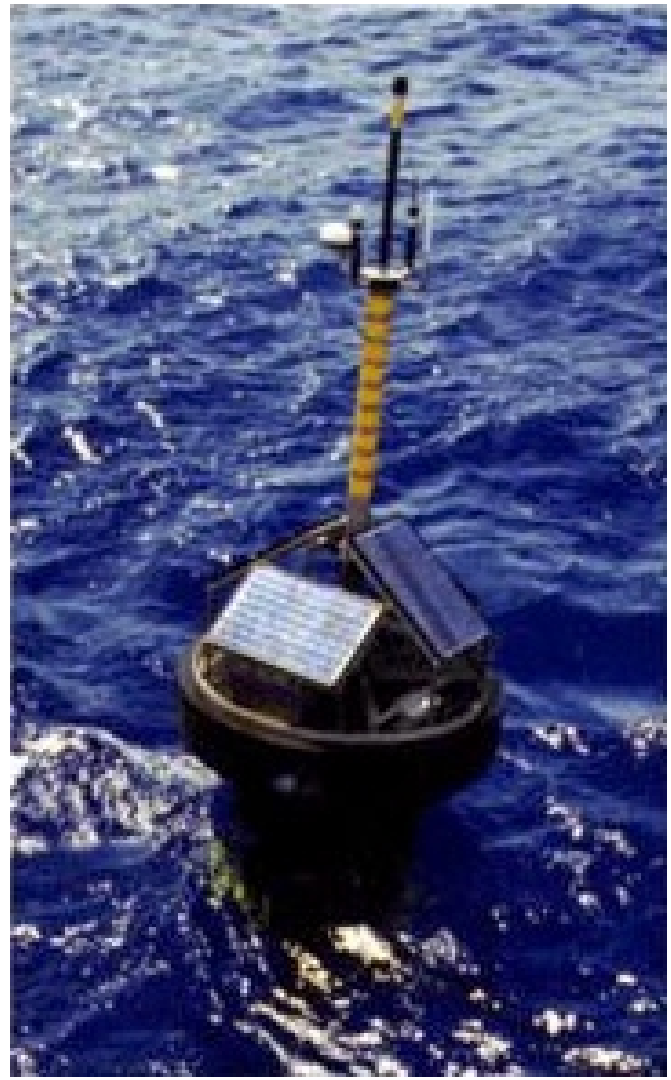
MOBY

- The Marine Optical Buoy (MOBY) is an in-water sensor that is permanently moored off the coast of Lanai in “clear water”
- MOBY measurements have been used to vicariously calibrate SeaWiFS, MODIS, OCTS, POLDER, OSMI data.



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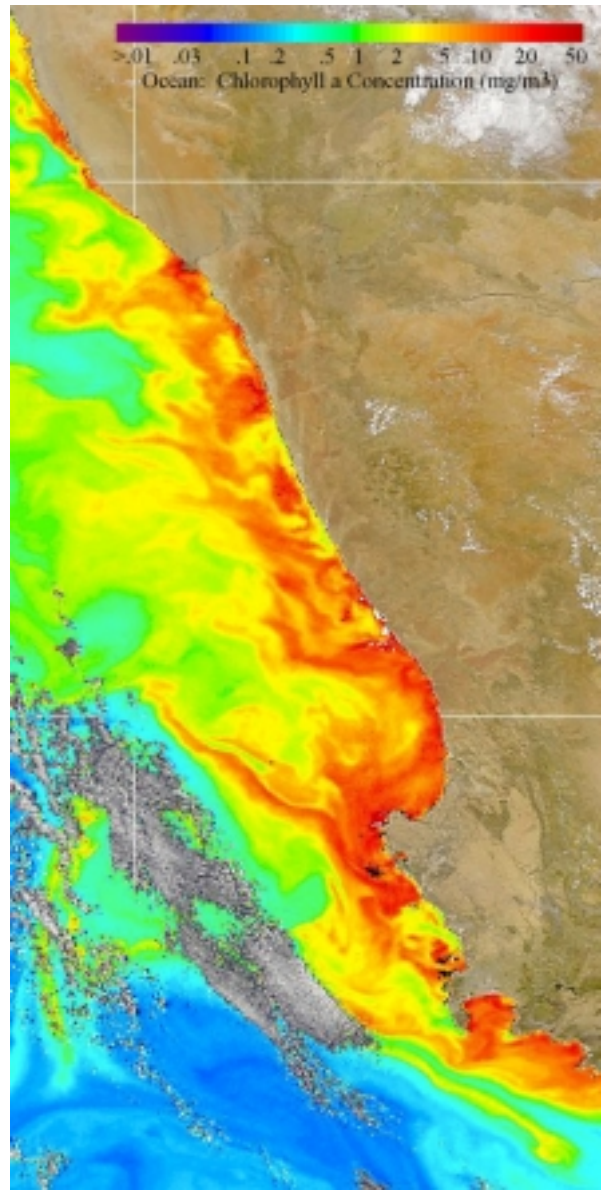
for SeaWiFS satellite data:

- calibration & geophysical algorithms are continuously assessed
- data are reprocessed when improved calibration parameters are produced
- current algorithms provide data with high quality and accuracy (8% globally)



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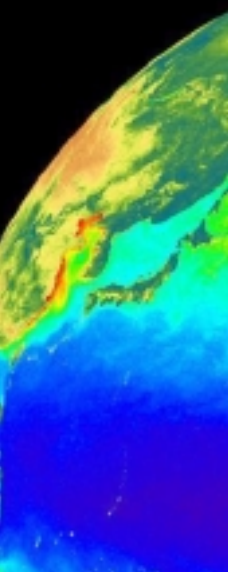

OCEAN COLOR MISSIONS:

Proof of concept: CZCS (US) 1978-86

Global

- OCTS (Japan) 96-97
- POLDER (France) 96-97
- SeaWiFS (US) 97- on
- MODIS AM (US) 99-on
- MISR(US) 99-on
- MODIS PM (US)
- MERIS (France) 2001?
- GLI (Japan) 2002?

Limited coverage

- MOS (Germany-India) 96-on
- OCM (India) 98-on
- OCI (Taiwan) 99-on
- OSMI (South Korea) 99-on

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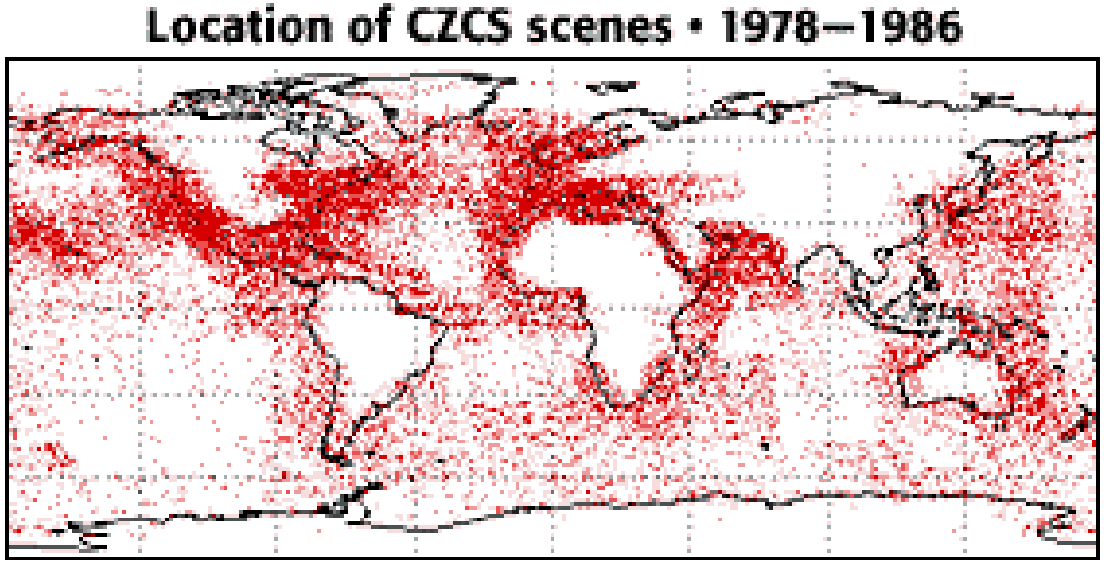
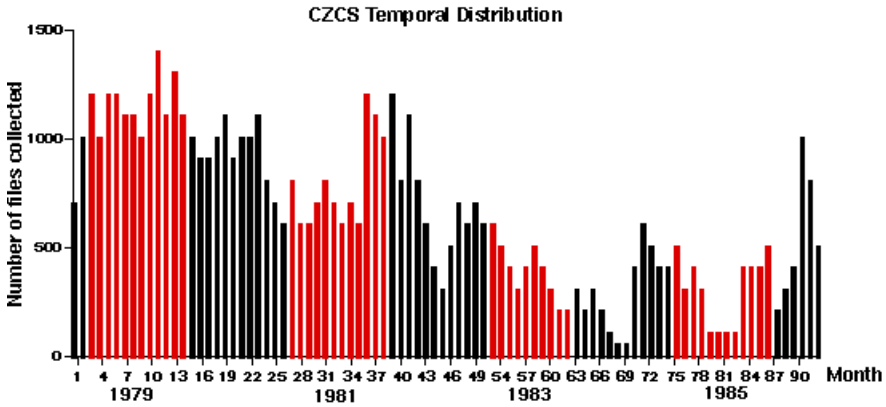
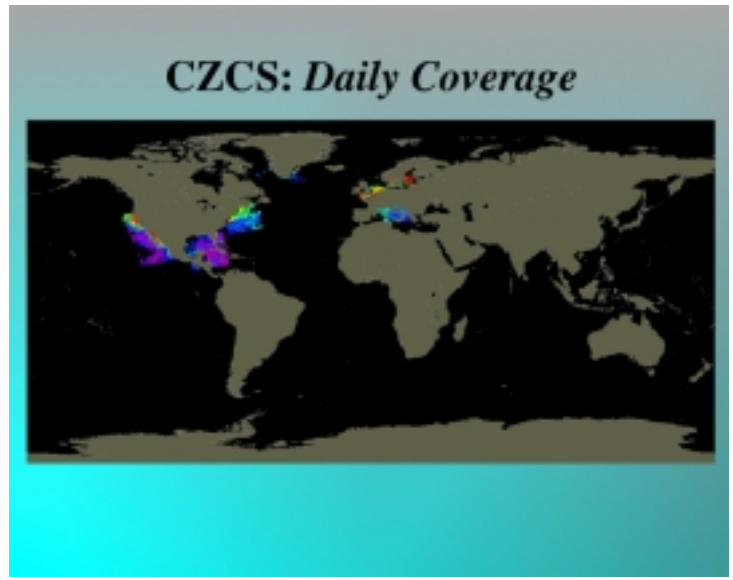


Bias in the CZCS data set





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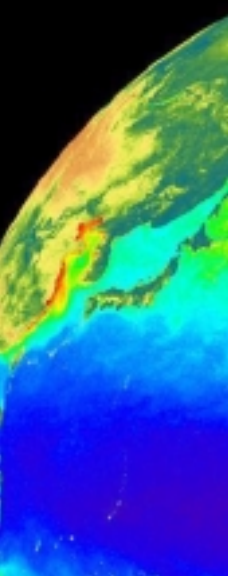
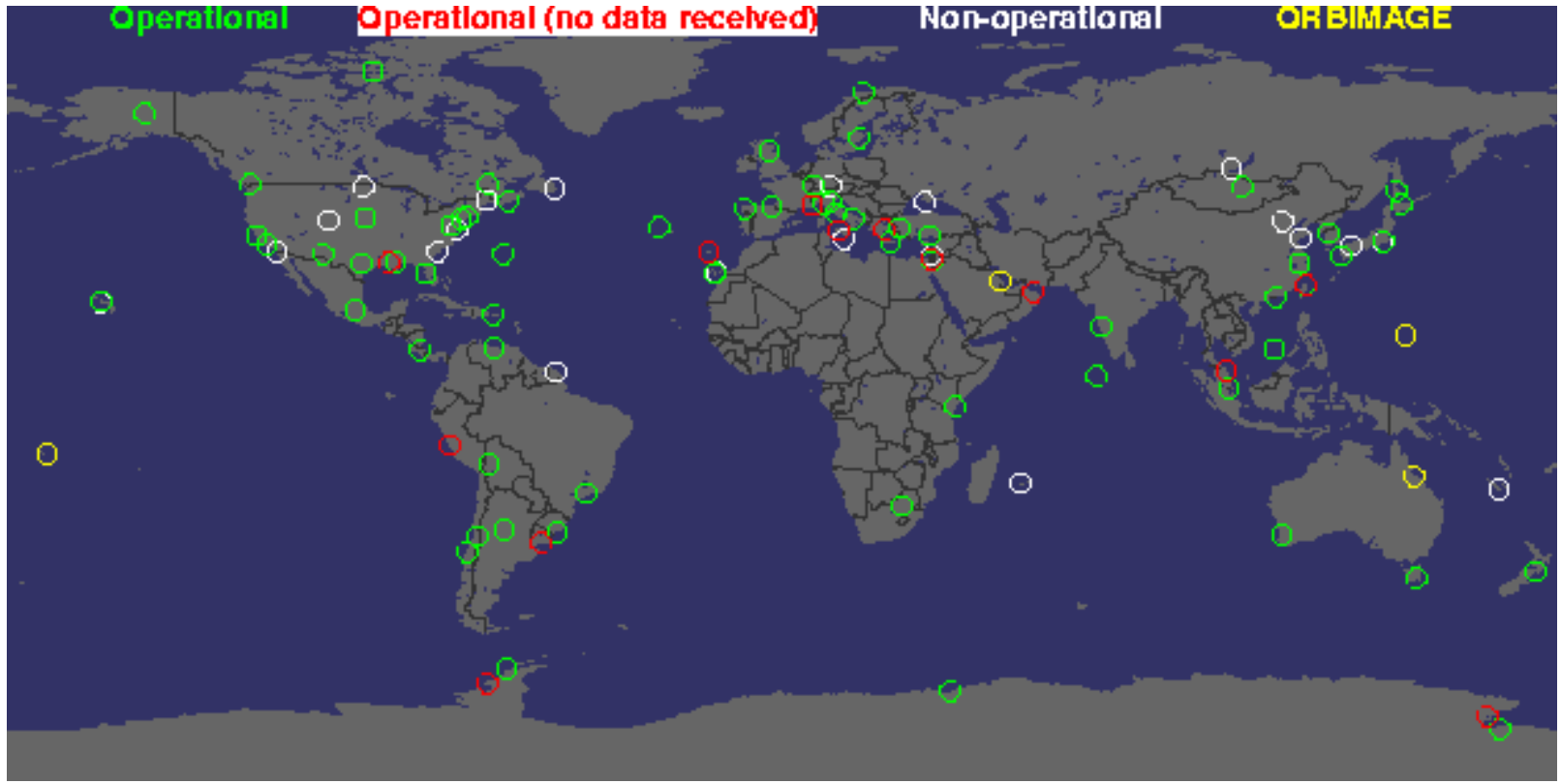


• SeaWiFS provides global coverage at 4.5 km nadir resolution, with 1.1 km resolution local area coverge [via a limited on-board recording space and direct broadcast High Resolution Picture Transmission (HRPT)].



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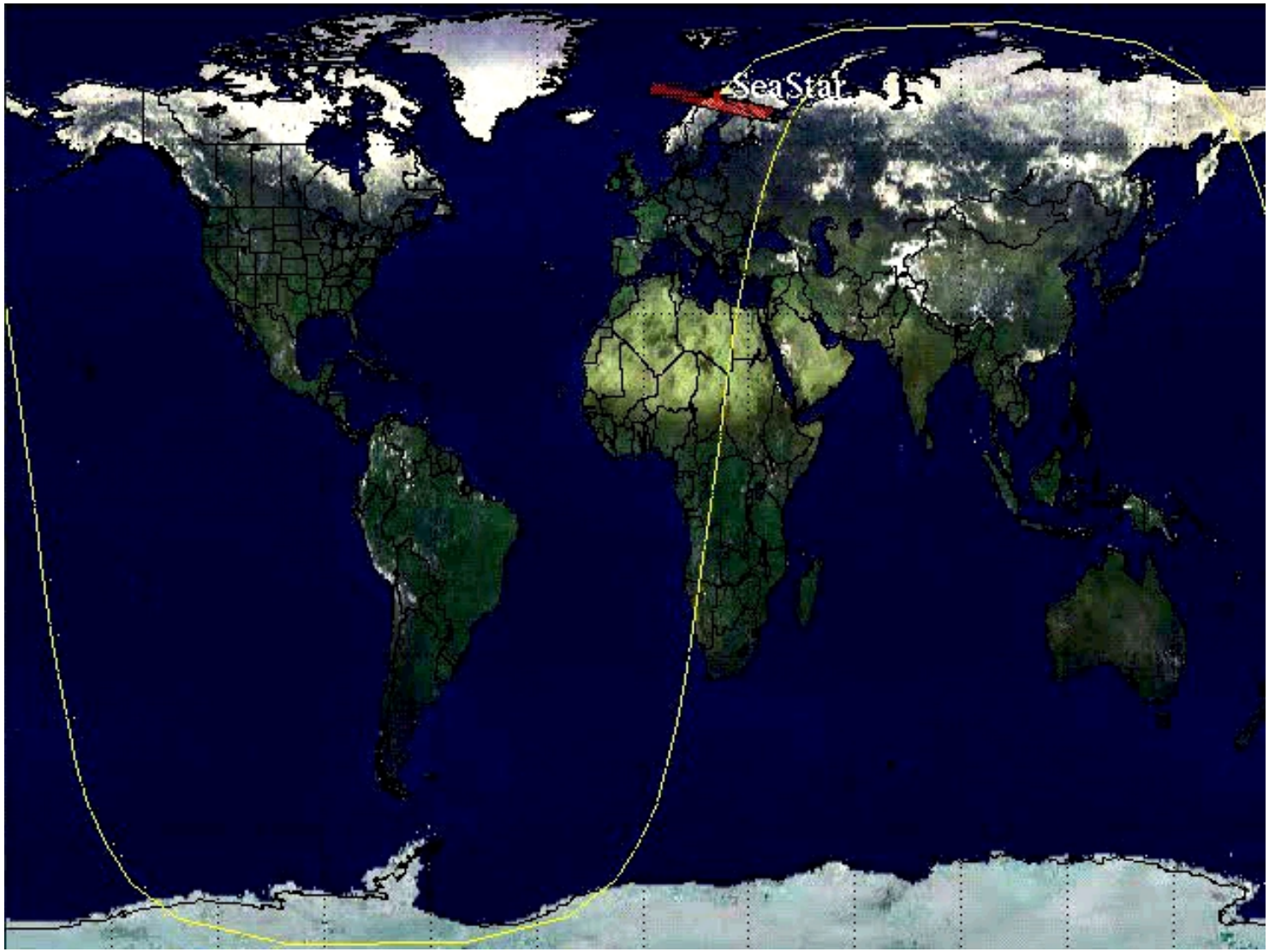
SeaWiFS daily coverage.



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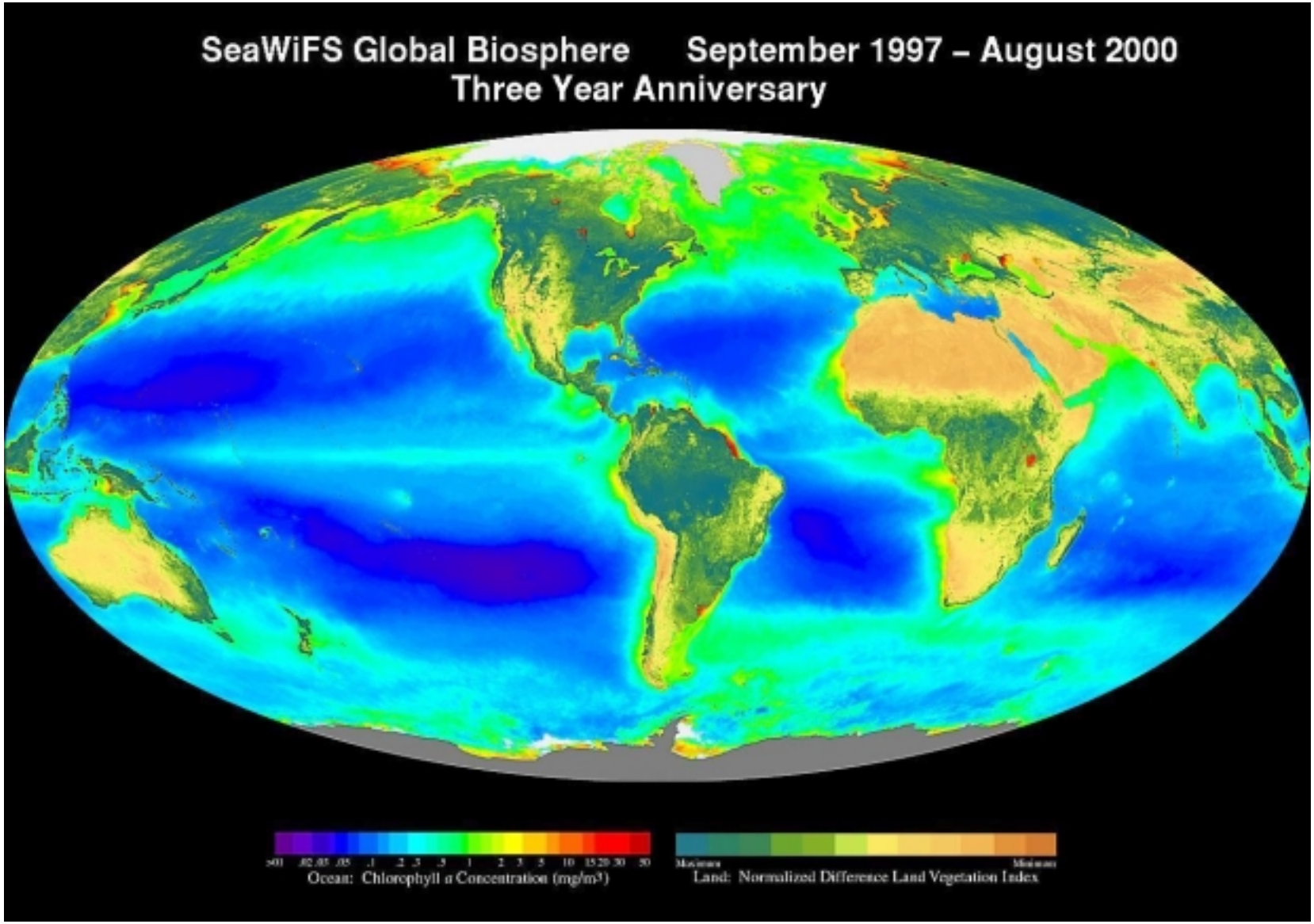
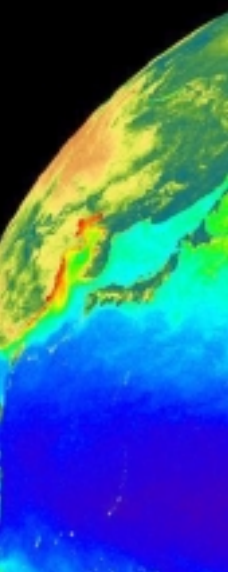

SeaWiFS Global Biosphere September 1997 – August 2000
Three Year Anniversary
.001 .02 .03 .05 .1 .2 .3 .5 1 2 3 5 10 15 20 30 50
Ocean: Chlorophyll a Concentration (mg/m³)
Land: Normalized Difference Land Vegetation Index

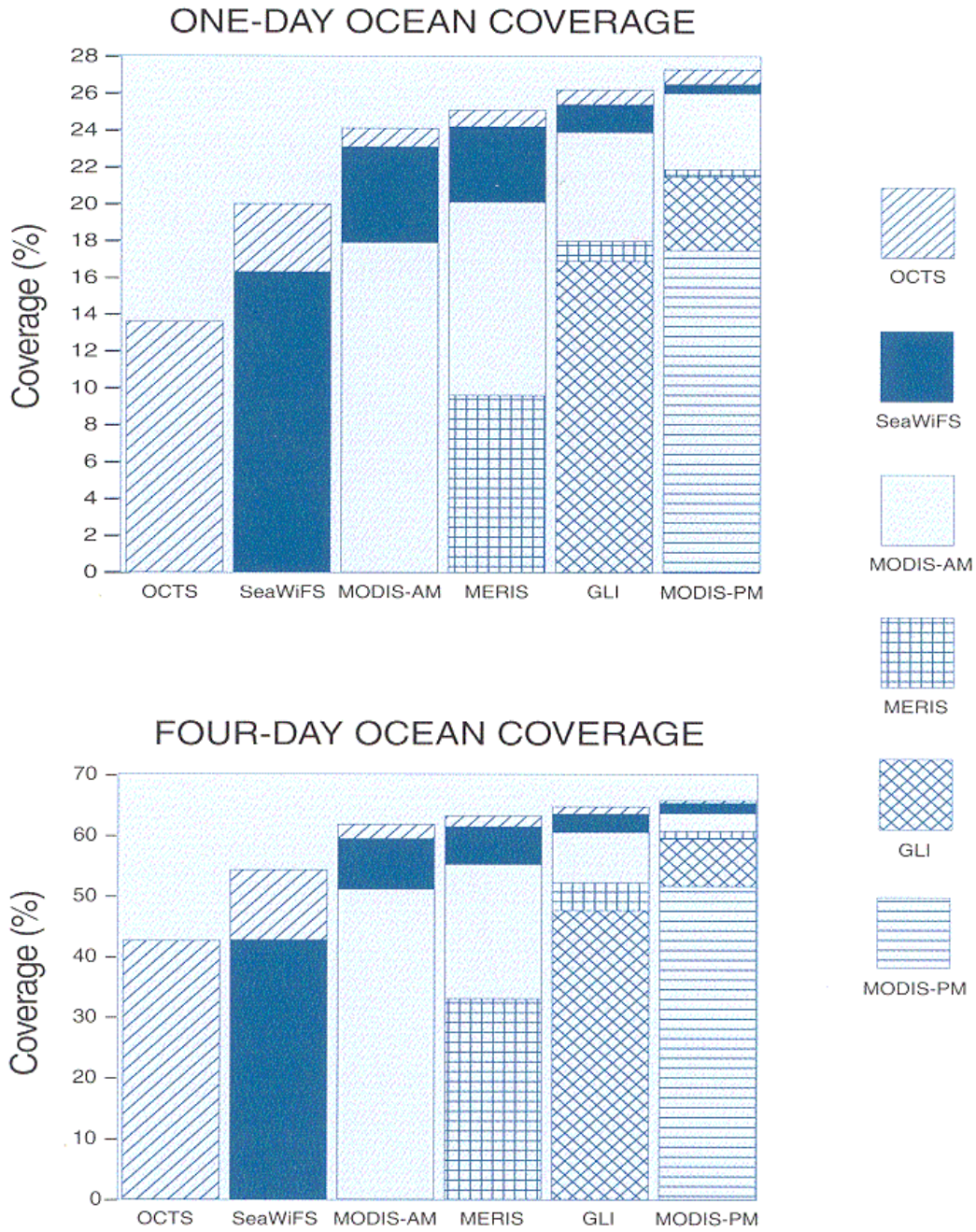
SIMBIOS



Hypothetical one-day & four-day estimates of ocean coverage using 6 global sensors.

Coverage is computed after removal of areas contaminated by excessive sun glint, and by cloud cover.

Clouds are allowed to change daily.



SIMBIOS

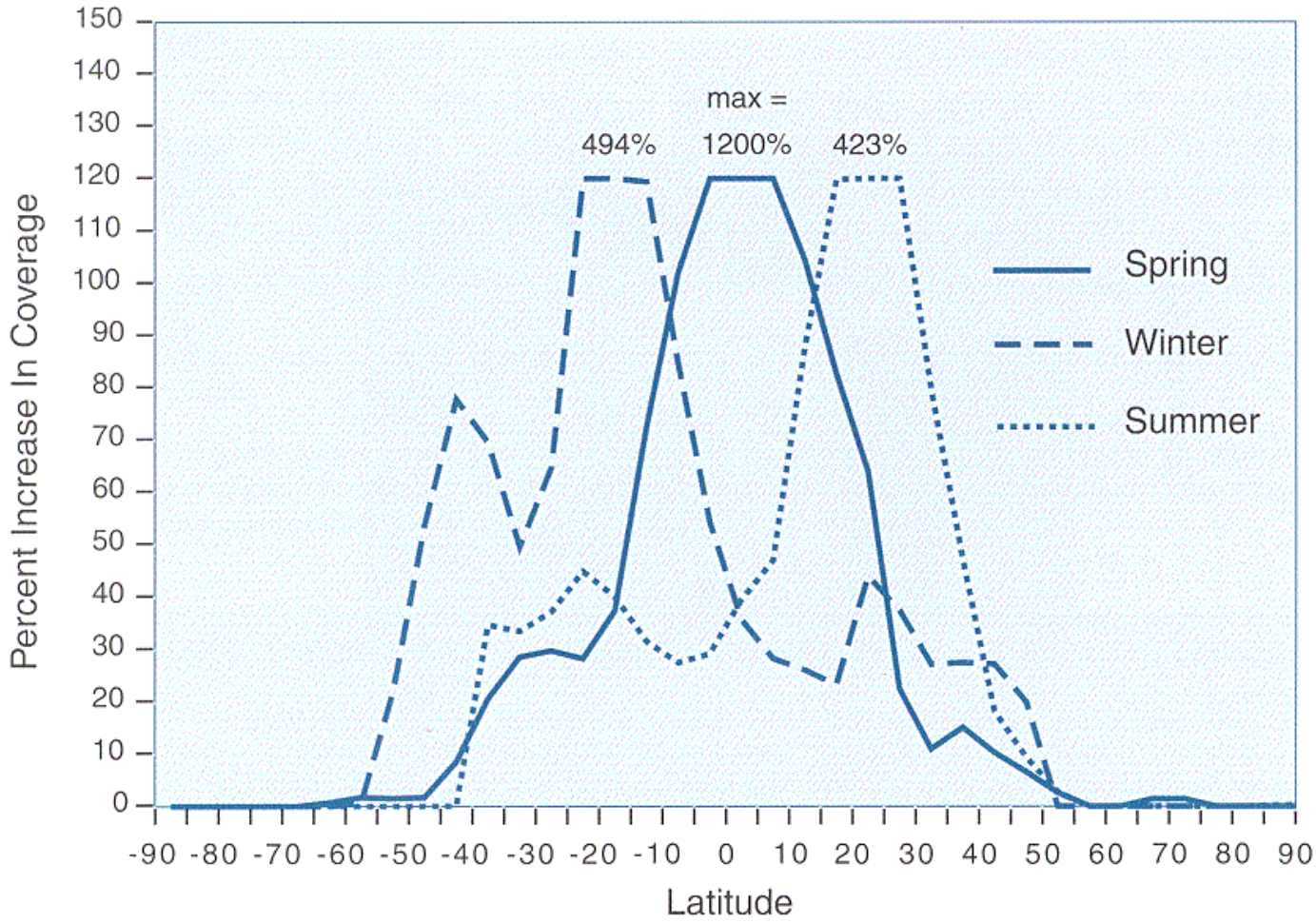
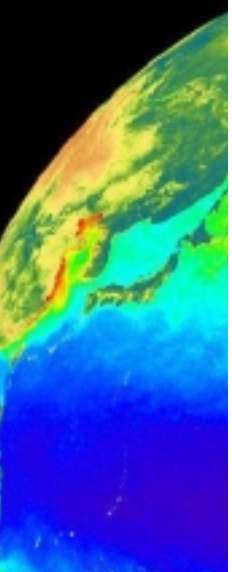


Figure 3. *Increases in coverage by latitude using combined data from SeaWiFS and MODIS-PM (from Gregg and Woodward, 1998). Individual mission coverages are not equally distributed about the global ocean surface, and the combination of data can vastly improve coverage in regions missed by one or another satellite. In this case, coverage increases are shown as percent, rather than a percent coverage of the ocean, e.g., a 10% increase means 10% greater coverage than that achieved by SeaWiFS alone.*

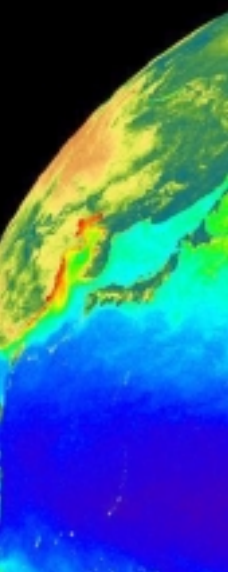
SIMBIOS



While each ocean color mission has its own validation effort….

- The Sensor Intercomparison and Merger for Biological and Interdisciplinary Ocean Studies (SIMBIOS) Program goal is to assist the international ocean color community in developing a multi-year time series of calibrated radiances that transcends the spatial and temporal boundaries of individual missions

SIMBIOS

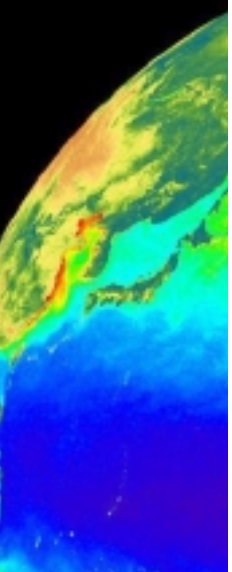


Specific objectives are:

- Quantify the relative accuracy of products from each mission
- work with each project to improve the level of confidence and compatibility among products, and
- develop methodologies for generating merged level-3 products

global or regional ocean color missions?

SIMBIOS

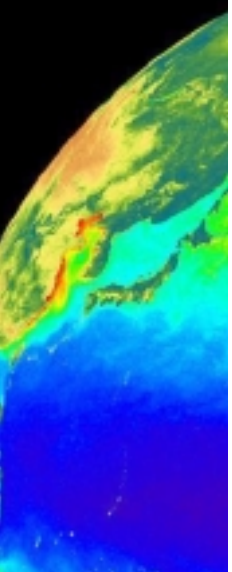


SIMBIOS has identified the primary instruments to be used for developing global data sets:

- OCTS, POLDER I & II
- SeaWiFS, MODIS (Terra and Aqua)
- MISR, MERIS and GLI

  Other missions will be tracked and evaluated but not considered as key data sources for global data set
- MOS, OCI and OSMI

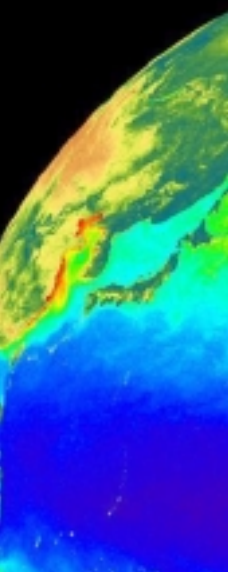
SIMBIOS



The challenge of coordinating the bio-optical and atmospheric in situ observations

- Set goals: accuracy/precision
- Define in situ variables to be measured or derived from measurements, for satellite ocean color sensor validation, and algorithm development and validation
- Group them in “required”, “highly desired” & “specialized measurements” &... have the investigators collected them

SIMBIOS

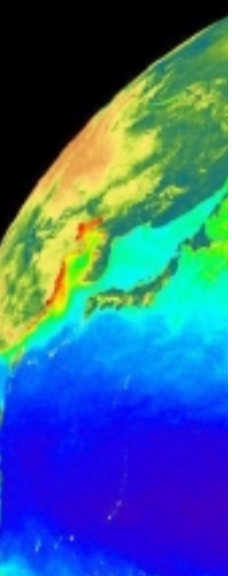


What you need to know

- clear definition of observations wanted
- uncertainties and source of errors
- data collection protocols
- instrument performance specification
- calibration protocols for all the instruments

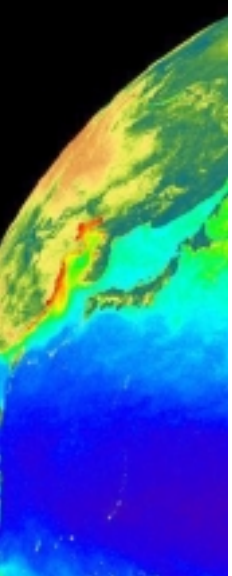
What you need to have

SIMBIOS



- Investigators collecting global in situ data, others working on bio-optical and atmospheric algorithms (i.e., NRA-99)
- R&D to investigate specific topics (examples development of SXR,SQM,etc.)
- Collaborations with Agencies, IOCCG etc.
- Processing and analysis capability
- A system to document info (NASA TM)
- Protocols in place with frequent updates
- Round robin of data and of calibration facilities
- In situ database & satellite data holdings

SIMBIOS



Functional structure

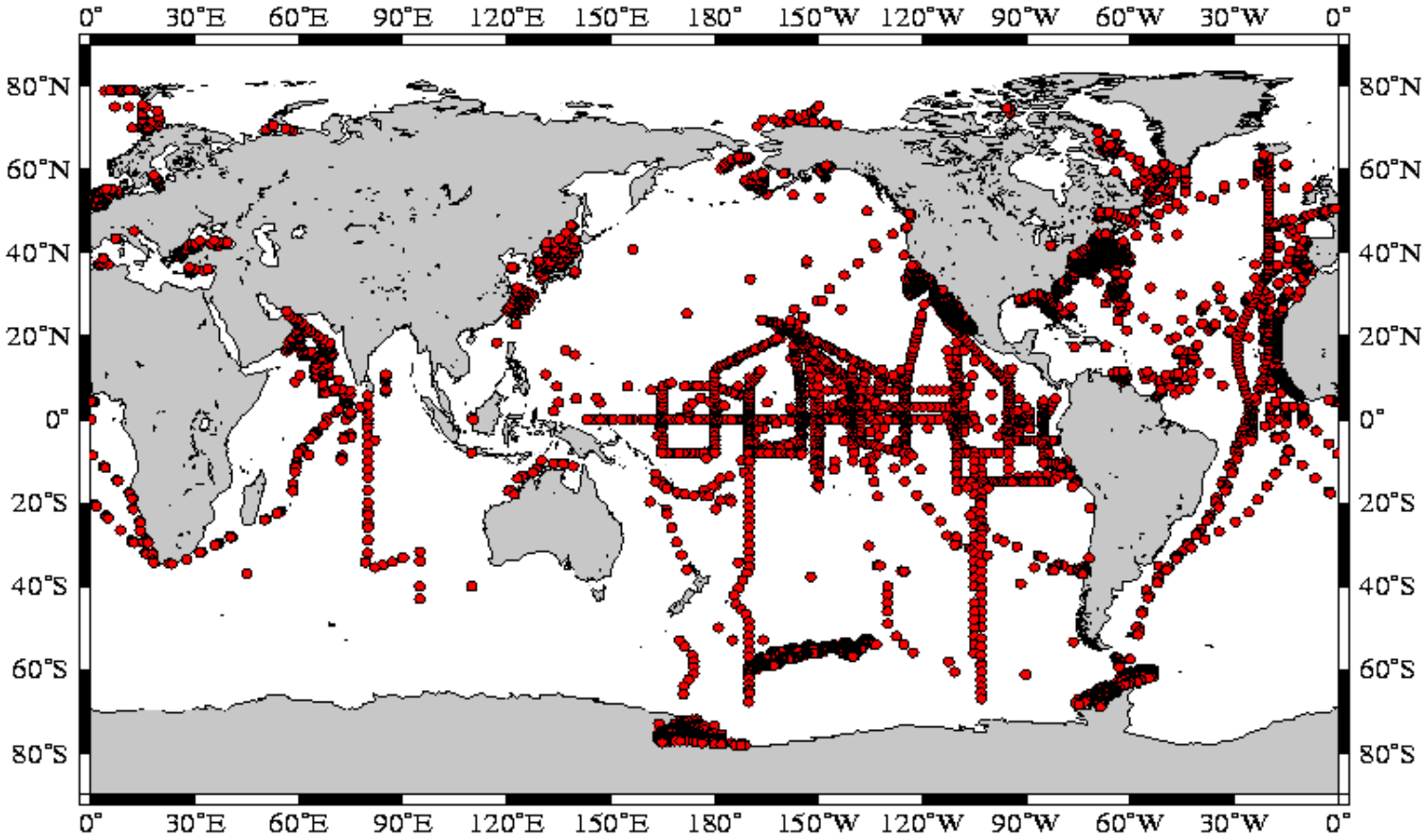
- **SIMBIOS Science Team**

  NASA HQ handles the team selection NRA-96 (1997-00) and NRA-99 (2001-03), but GSFC manages contracts, work statements and annual reviews.

- **SIMBIOS Project Office** provides technical, management, coordination support to the Program and collaborates with space agencies (e.g., NASDA, CNES) & other organizations (e.g., IOCCG, JRC).

SIMBIOS

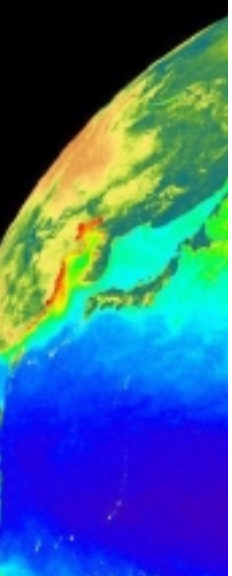
Bio-optical & Atmospheric Data archived in SeaBASS



SIMBIOS Project

- Satellite Data Processing
- Data Product Validation:
  - Algorithm Validation and Calibration
  - Match-up Analysis
  - SeaBASS Interface
  - Satellite over-flight support
- Sensor Engineering and Calibration:
  - Field Instrument Pool
  - Calibrations (Microtops, Prede, Cimel & SIMBAD)
  - Calibration RR (SeaWiFS Transfer Radiometer)
- Project Office:
  - Science Team Support
  - Procurement & Financial Analysis Support
  - Administration & Technical Support

SIMBIOS



Product Validation

- **SeaWiFS ongoing validation**
  - *aerosol optical thickness (AOT) products*
  - *match-up analysis (e.g. chlorophyll)*
- **OCTS, MOS, POLDER and OSMI Validation**
  - *Match-up comparison with field data completed*
- **OCTS-POLDER**
  - *Data comparison completed*
- **OCTS-GAC**
  - *Global data reprocessing ongoing*
- **MOS-SeaWiFS**
  - *Data comparison and data merging ongoing*

SIMBIOS

SeaWiFS:

Equatorial crossing time: 12:00 am

Resolution (Km): 1.13

Swath (KM) 2800
Recurrent period: 16 days

2days global coverage

MOS:

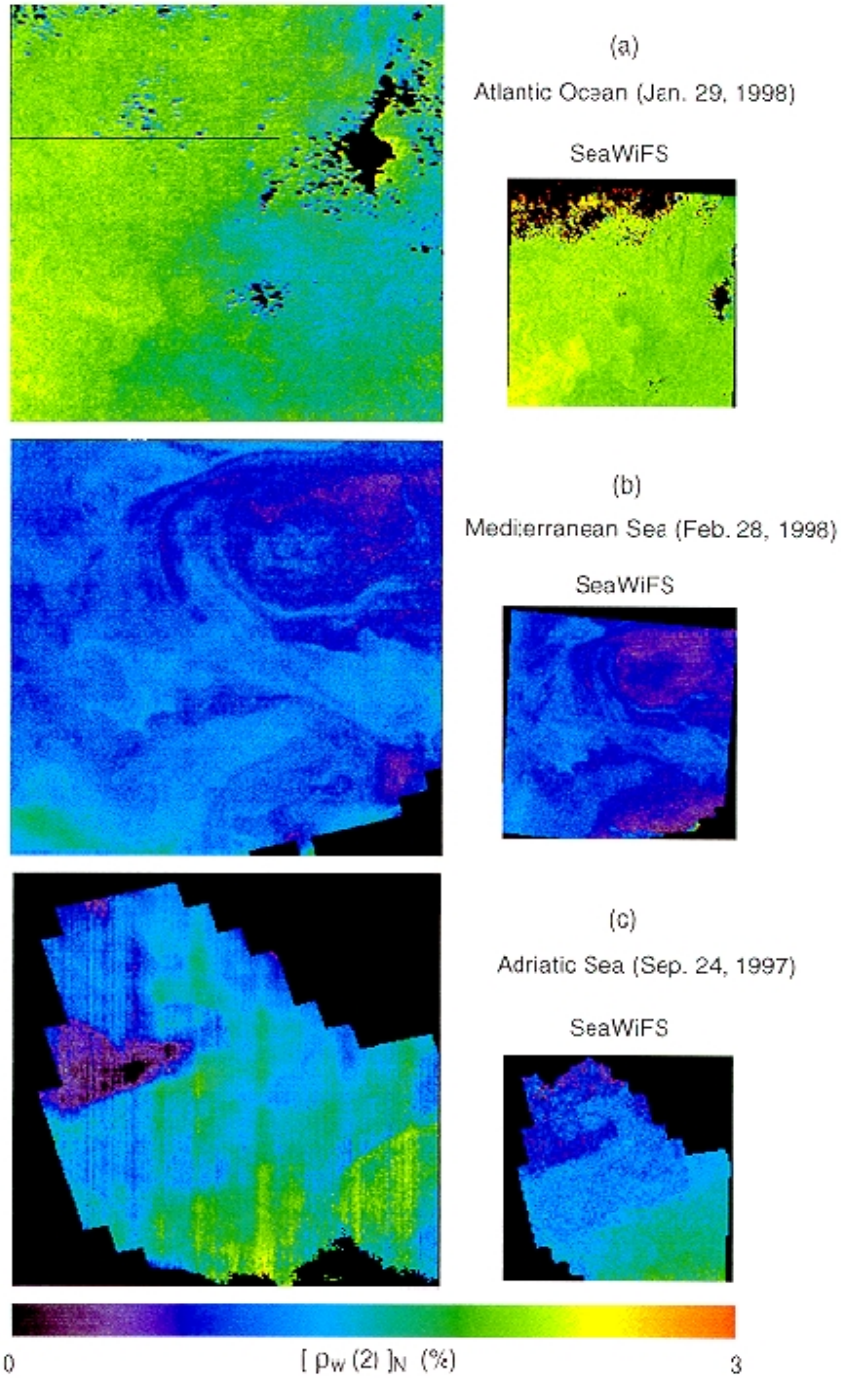
Equatorial crossing time: 10:30 am

Resolution (Km): 0.52

Swath (KM) 200

Recurrent period: 24 days

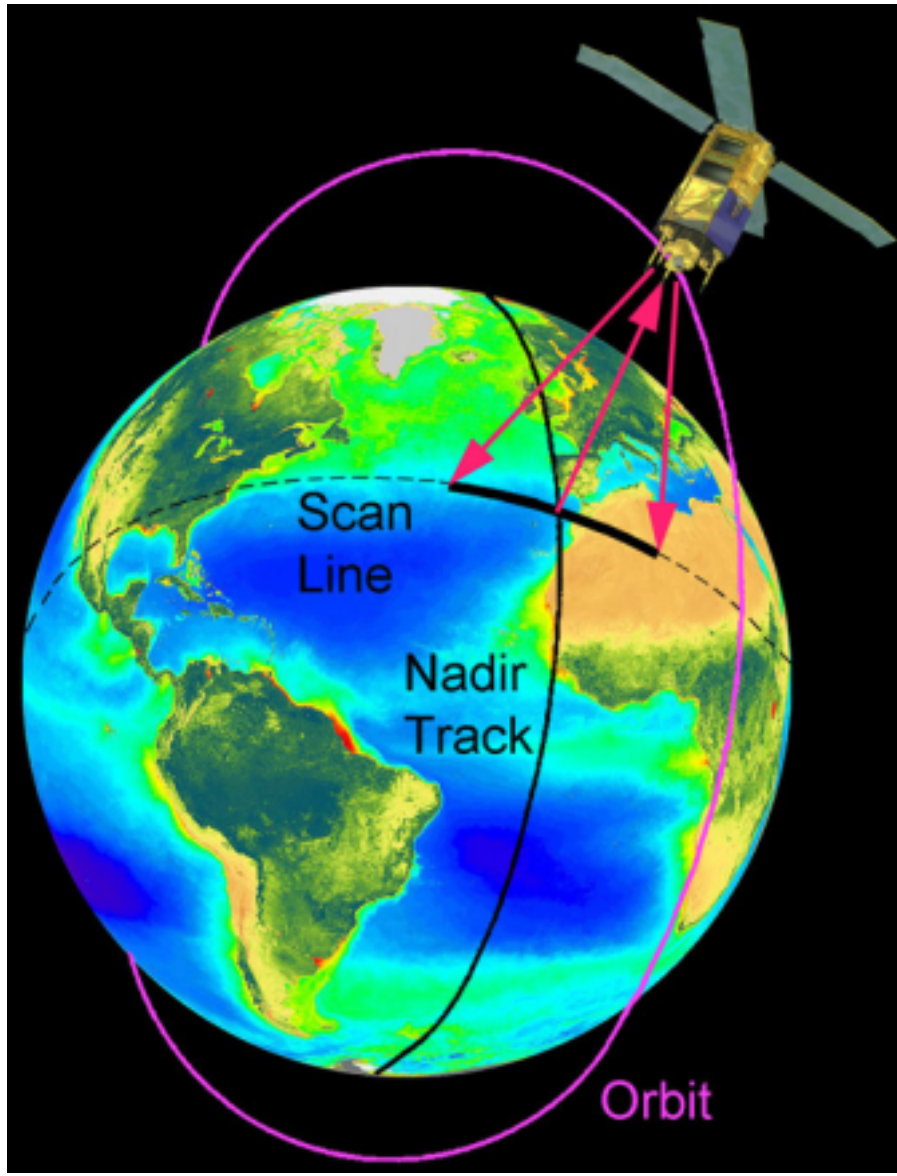
No global coverage



SIMBIOS

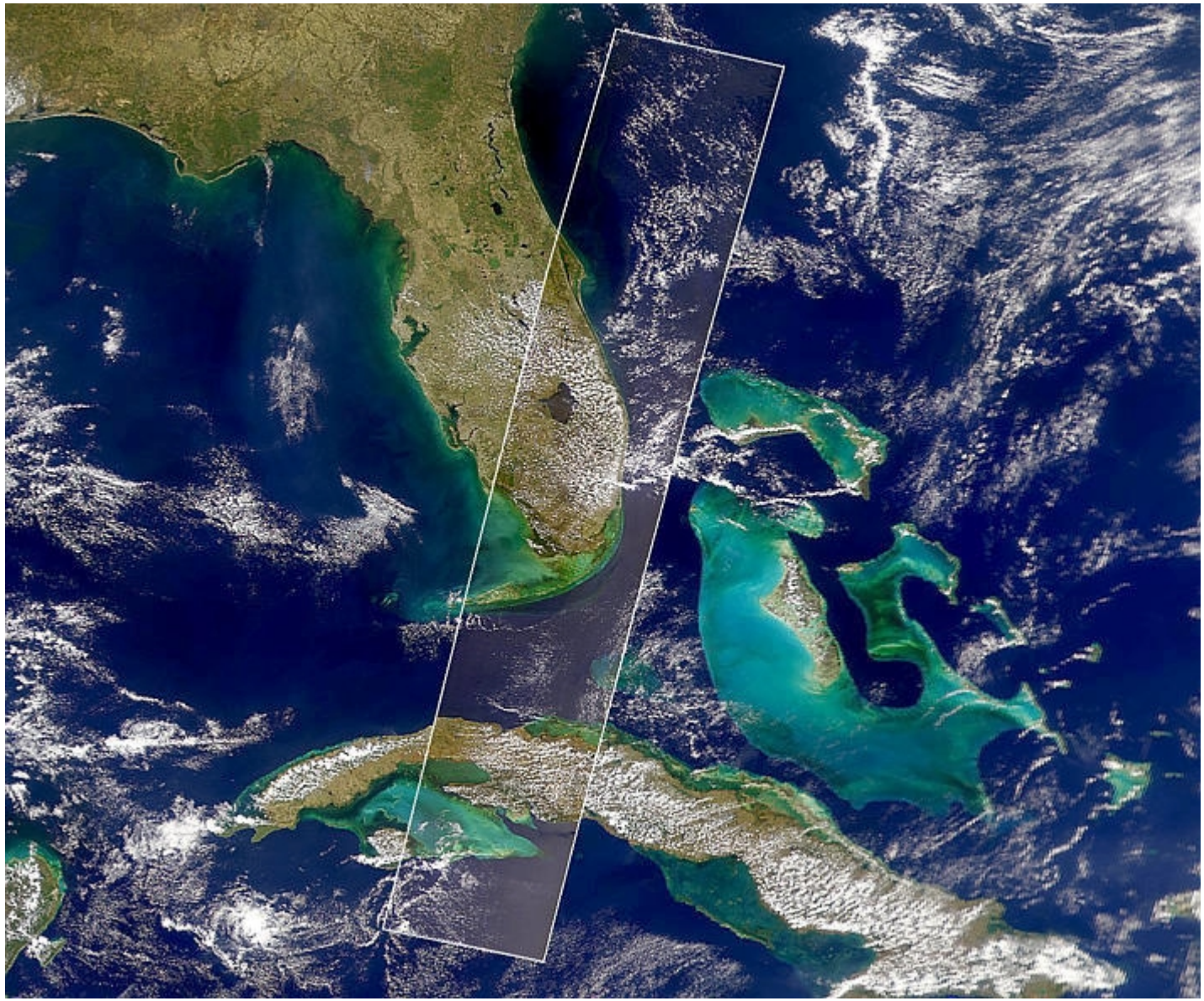
Satellite Orbit

- the SeaWiFS sensor is the only sensor on board the SeaStar/ Orbview-2 Satellite
- satellite has a polar orbit, north-south on sunlit side
- orbit crosses equator at local noon



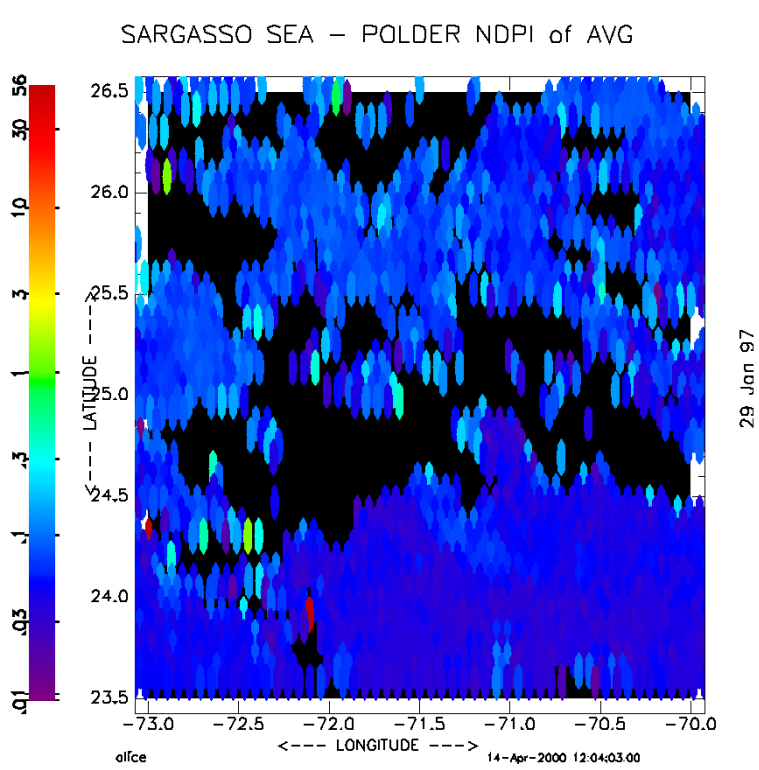
SIMBIOS

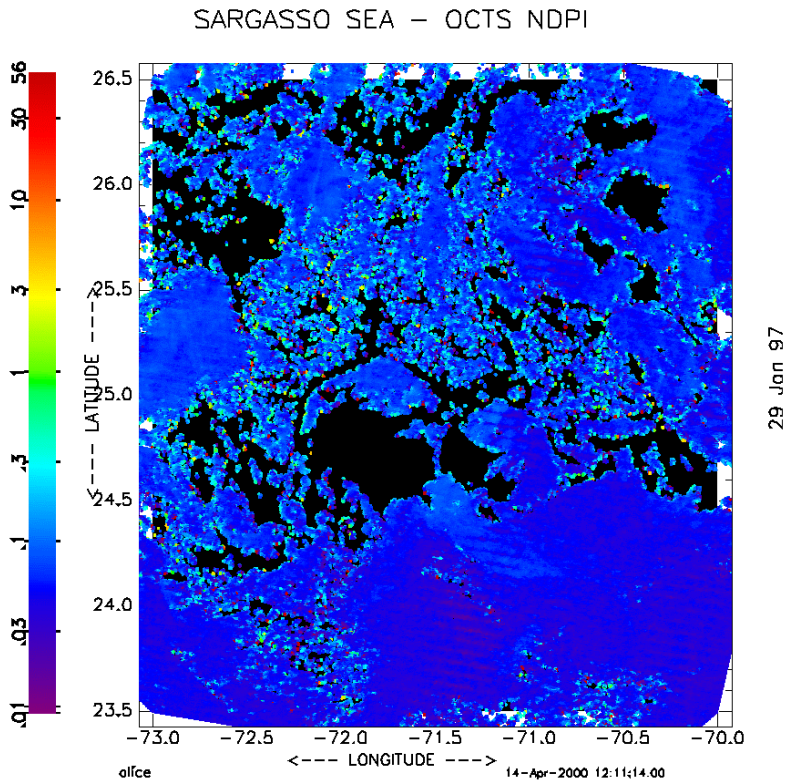
SeaWiFS-MOS Overlay, 23 March 1999



SIMBIOS

OCTS-POLDER comparison





	Polder	OCTS
Resolution (Km)	**6 x7 Km**	**700 x 700 m**
Global coverage	**1 day quasi-global**	**3 days**
Recurrent period	**41 days**	**41 days**

SIMBIOS

Time gap:

Polder ends on 06/97

SeaWiFS start on 09/97

Chlorophyll-a (mg/m3)

30.000

3.000

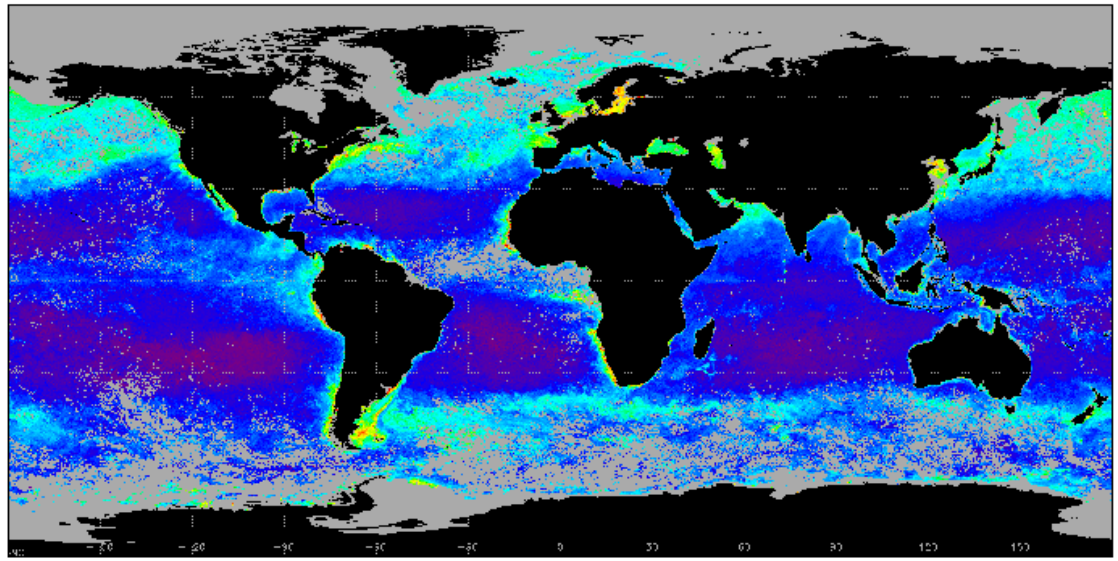
0.300

0.030

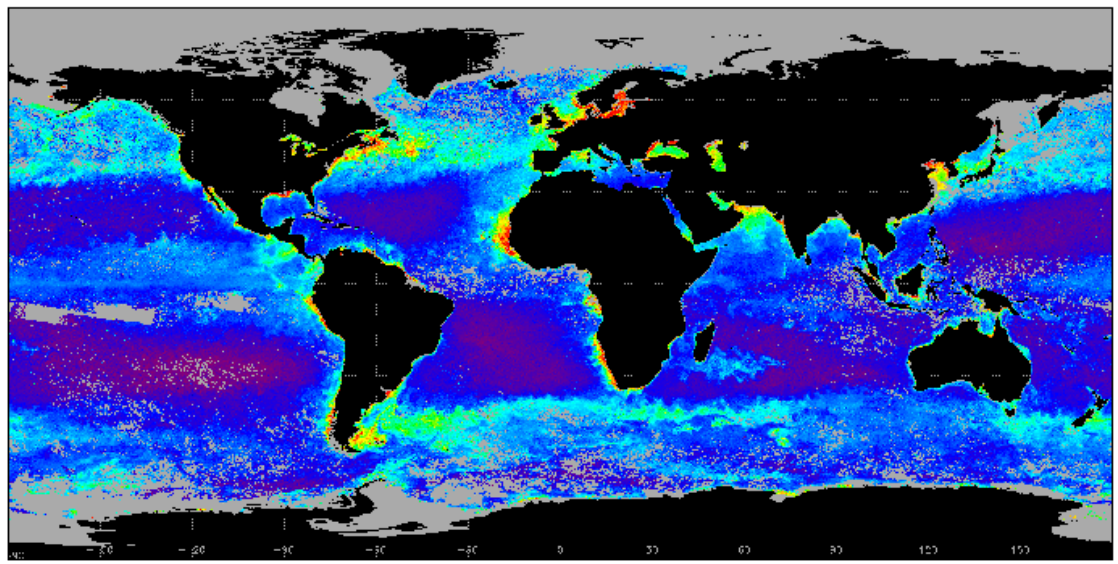
POLDER data :
LOA/LSCE/CNES/NASDA

SeaWiFS data :
Orbimage/NASA

POLDER, 9703



SeaWiFS, 9903



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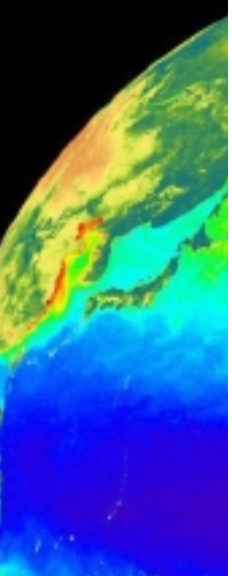


How can this science be used in the classroom?

•Define the science question with correct space and time scales. Identify the satellite data (SeaWiFS, MODIS). Request the data and software

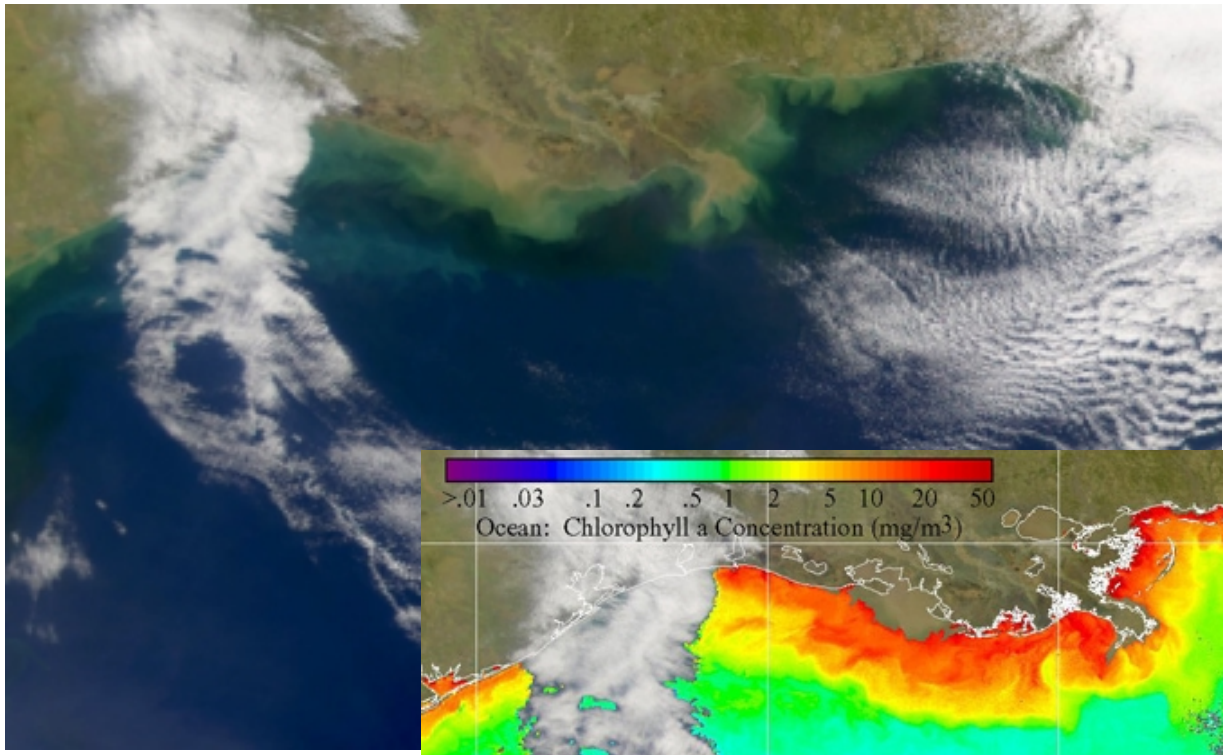
Science: Chesapeake Bay-circulation, biomass estimate & seasonality pattern study; estimate how many and how long we had red tides this year in world; monitor coral reef ecosystem; identify upwelling regions in the world; circulation: gyres, currents, eddies and jets

Atmospheric phenomena: cyclones, smoke,pollution,dust, volcanoes -follow space and time evolution

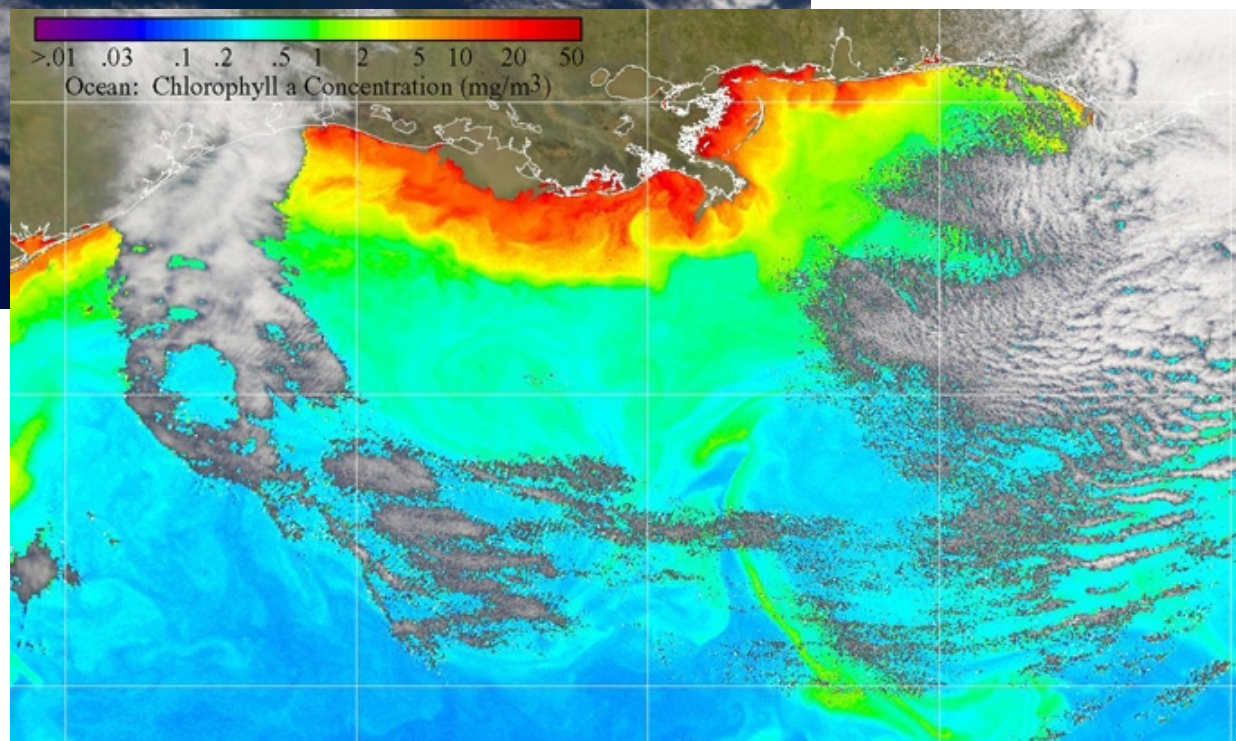
Social studies: hurricane disaster relief, rain forest deforestation, fire extensions- model areas of risk

SIMBIOS

Monitoring Algal Blooms



Feb. 25, 1999

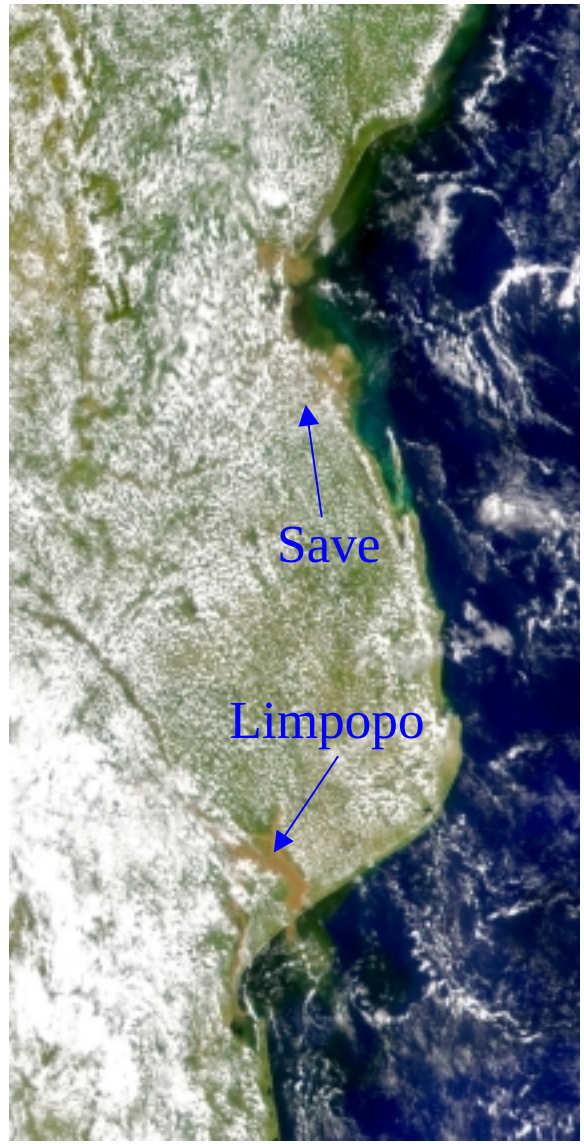


SIMBIOS

Flood Monitoring

Flooding in Mozambique

- Limpopo and Save rivers overflowed their banks
- flooding most severe at river mouths
- extensive damage to coastal areas
- SeaWiFS can be used to map and quantify damage



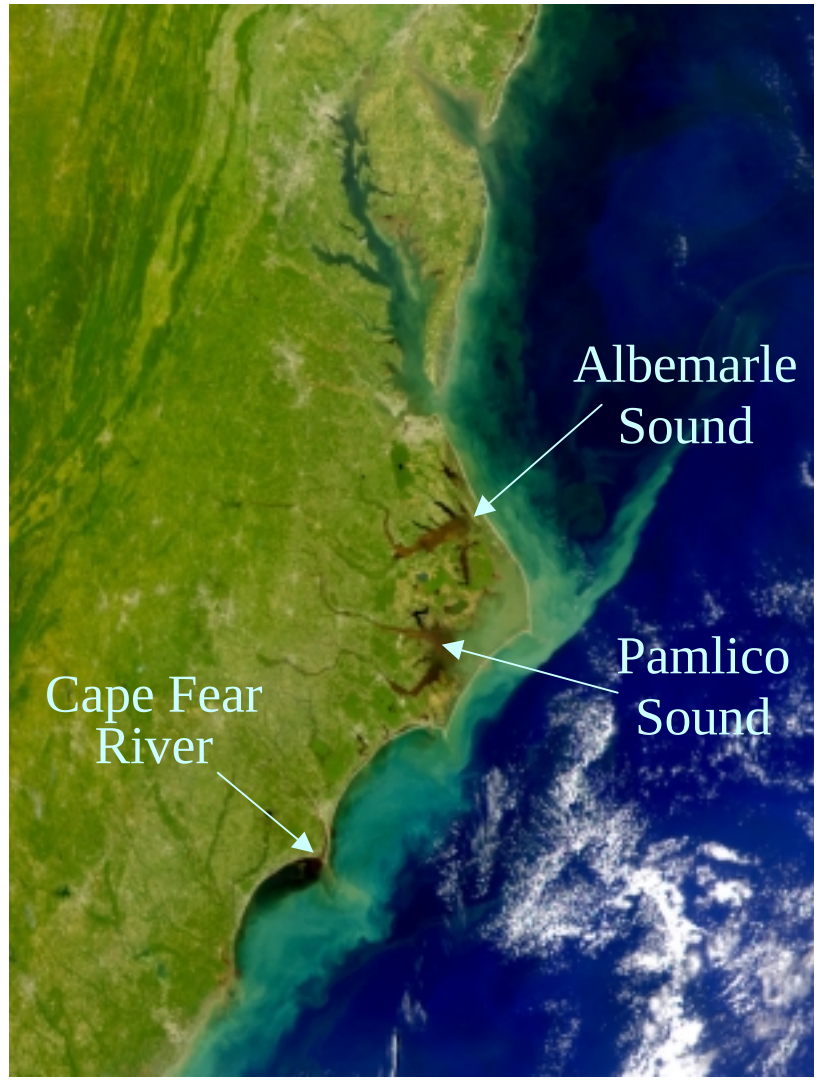
SIMBIOS

Hurricane Disasters

Hurricane Floyd

Ecological disaster

- massive flooding
- rivers carried
  - sediment
  - sewage
- discharged into coastal areas
- resulted in anoxic conditions in bay



Sept. 23, 1999

How can I get this data?

Satellite data easily available at:

SeaWiFS at http://seawifs.gsfc.nasa.gov/SEAWIFS.html

***In situ* data through SIMBIOS**

SeaBASS at http://seabass-da.gsfc.nasa.gov/dataordering.html

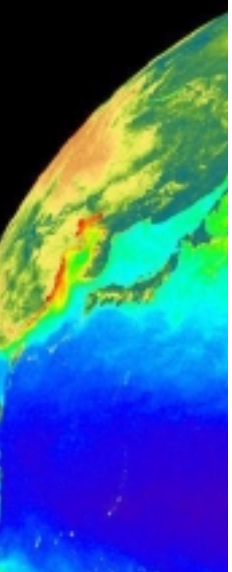
Satellite software through SIMBIOS & SeaWiFS

SeaDAS at http://seadas.gsfc.nasa.gov/

SeaWiFS Teaching Material

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/poster_supplement.html

SIMBIOS

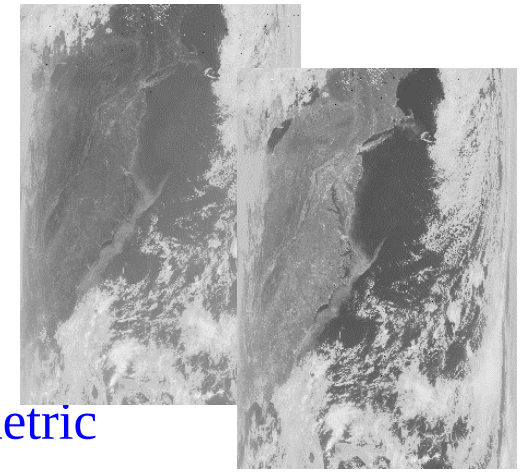


Extra

EOS Product Levels

Level 0

- unprocessed instrument/payload data
  - includes communications artifacts
  - duplicate data removed



Level 1A

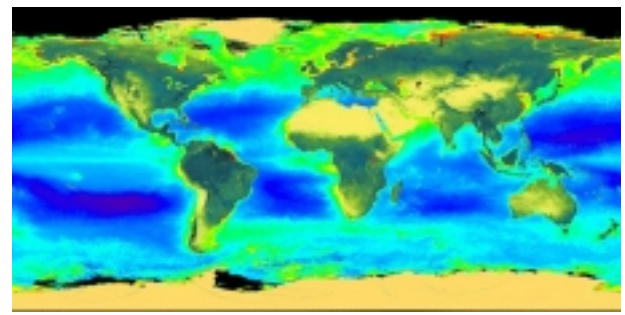
- unprocessed instrument data
  - time referenced and geolocated
  - annotated with ancillary information, (radiometric and geometric calibration coefficients)

Level 1B

- Level 1A data processed to top of atmosphere radiances by applying radiometric calibration

Level 2

- Atmospherically corrected Level 1B data
- Derived geophysical variables at same resolution as Level 1 data



Level 3

- Mapped onto uniform grid
  - spatially and temporally averaged

SIMBIOS

Getting SeaWiFS Data

SeaWiFS data is distributed through the Goddard DAAC

http://daac.gsfc.nasa.gov

- need to become an authorized SeaWiFS user

  http://seawifs.gsfc.nasa.gov/cgibrs/apply.pl?page=du
- once authorization is approved, DAAC issues a password
- can browse DAAC database and order specific data (password not required for browsing)
- can set up a subscription, where data from a specified area is sent automatically whenever it becomes available.
- data is delivered either by magnetic tape or ftp (notified by e-mail when ftp order is ready to be picked up)